

Inventors and Engineers of Old New Haven

1638



1838

New Haven Colony Tercentenary Publications

New Haven, Connecticut

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Sheffield Hall after 1866.

NEW HAVEN TERCENTENARY PUBLICATIONS

Inventors and Engineers of Old New Haven


A Series of Six Lectures given in 1938 under the
auspices of the School of Engineering
Yale University

Edited by RICHARD SHELTON KIRBY

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NEW HAVEN, CONNECTICUT

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CONTENTS

	Page
Introduction	1
Eli Whitney	3
Early New Haven Inventors	11
Early Yale Inventors	25
Early Yale Engineers	37
Formative Years of New Haven's Public Utilities	55
Founding of the Sheffield Scientific School	83
Index	109

nitney	<i>Facing page</i> 12
of Cotton Gin	<i>Facing page</i> 12
ey Jerome	<i>Facing page</i> 16
Goodyear	<i>Facing page</i> 16
ishnell Submarine	<i>Facing page</i> 27
b. Morse	<i>Facing page</i> 31
ng First Telegraphic News Message	<i>Facing page</i> 32
nitney Blake	<i>Facing page</i> 34
Stone-breaker	<i>Facing page</i> 34
der Catlin Twining	<i>Facing page</i> 46
Mansfield	<i>Facing page</i> 46
Farnam	<i>Facing page</i> 48
Train on Northampton Railroad	<i>Facing page</i> 48
laven's Original Gas Works	<i>Facing page</i> 64
Lamp, 1848	<i>Facing page</i> 64
Jew Haven Horse-cars	<i>Facing page</i> 65
'telephone Switchboard	<i>page</i> 82

INTRODUCTION

SAMUEL WILLIAM DUDLEY

DEAN, SCHOOL OF ENGINEERING, YALE UNIVERSITY

FEW cities of moderate size are as widely known as New Haven for extent and quality of manufactured products, coupled with leadership in educational affairs. The city's reputation in both fields is a cherished heritage from early colonial days. A century and a half ago Yale was a collegiate school, established to train Connecticut youth for service in church and civil state. At about this time New Haven, still a small town dependent largely on its shipping, began unaccountably to produce and to attract to itself in increasing numbers young men of outstanding originality and vision in mechanical and industrial affairs. In the course of years not a few of these men hit upon inventions or improved methods that affected the social, economic and industrial life of the nation, indeed of the world. The list need only be suggested here; the submarine, the cotton industry, the interchangeable parts system of manufacture, firearms, the truss bridge, rubber, clocks, hardware, matches, artificial refrigeration, the telegraph, modern highway and concrete construction, railways, the petroleum industry, the telephone central exchange. All these came into being or were to some extent cradled here, at the hands of men trained either in shop or college, or both. Among the more widely known of this group are Eli Whitney, David Bushnell, Ithiel Town, Charles Goodyear, Samuel Finley Breese Morse, Eli Whitney Blake, Alexander Catlin Twining, Chauncey Jerome, Henry Farnam. Our city is proud to have had among her citizens these pioneers in science, engineering and industry, men whose ingenuity, resource and vision have left their indelible impress upon our civilization.

It therefore seemed fitting that, as a prelude to New Haven's Tercentenary celebration, the School of Engineering of Yale University should arrange a series of lectures which would call the roll of local inventors, engineers, and practical scientists of other days whose achievements have brought fame to both City and Uni-

versity. Accordingly, the following lectures were delivered in Strathcona Hall during the winter and spring of 1938:

Eli Whitney

Joseph Wickham Roe

Early New Haven Inventors

Joseph Wickham Roe

Early Yale Inventors

Ralph Henry Gabriel

Early Yale Engineers

Richard Shelton Kirby

The Formative Years of New Haven's Public Utilities

Henry Hotchkiss Townshend

The Story of the Founding of the Sheffield Scientific School

Russell Henry Chittenden

The Foremen's Club of New Haven and the Local Sections of the National Societies of Civil, Electrical, and Mechanical Engineers assisted in sponsoring the series.

Much of the information and many of the illustrations used by the lecturers were assembled from obscure sources after patient search for original and long-forgotten material, or from personal recollections of earlier days. It is eminently fitting that the results of these labors in honor of some of her pioneer citizens should find permanent place among the records of New Haven's Tercentenary celebration.

ELI WHITNEY

JOSEPH WICKHAM ROE

VISITING PROFESSOR OF INDUSTRIAL ENGINEERING, YALE UNIVERSITY

IN the spring of 1789, the same year in which Slater started cotton manufacture in the United States, there walked on to the Yale College campus, which then had only two buildings a Freshman from a farm in Westboro, Massachusetts, who was to affect not only the life of this city but the political history of the country and the industrial life of the whole world. Eli Whitney was older than his classmates, quiet in manner, a good but not a brilliant student, with a flair for everything mechanical. He had shown this from boyhood. From the time he was twelve he made and repaired violins. When he was sixteen he induced his father to start making nails, first by hand, then by crude machinery of his own devising, then to employ workmen to help them. From the time he was eighteen he taught district school for five winters attended Leicester Academy in the summers, and he finished his preparation for college with the Rev. Mr. Goodrich of Durham. He entered Yale at twenty-three and graduated in September of 1792, intending to study law. By a series of queer twists which life brings, within a few months he was launched on an entirely different career.

To clear up debts incurred at college and to provide means for his law training, he engaged to act as tutor in the family of a planter in Georgia, and with this in view he sailed from New York for Savannah shortly after graduating. On the way he met Mrs. Nathaniel Greene, widow of General Greene of the Revolution and Phineas Miller, Yale graduate of 1785, who was a lawyer and the manager of her estate, and whom she afterward married. Upon landing he went to visit them at Mrs. Greene's plantation at Mulberry Grove near Savannah. While there, during a conversation at a week-end party of former Revolutionary officers, the conversation chanced to turn on the distressed financial condition of the South and the need of some way of cleaning cotton from its seed.

Georgia was too far south for successful tobacco growing. Rice and indigo had been tried, with only indifferent success. The growing of *long* staple cotton had been well started on the sea islands some years before, but the land area available for this was small. Green seed or *short* staple cotton could be grown over wide areas, but was not profitable because of the tenacity with which the fiber clung to the seeds. It was a day's work to separate a single pound of staple. If means could be found to do this satisfactorily and economically the raising of cotton would be profitable throughout almost the whole of the South. At Mrs. Greene's instance this problem was put up to Whitney.

Happily, by another twist of fortune, the planter who had engaged Whitney welshed on his agreement, and Whitney was free to work on the problem. It was then winter and out of season for cotton growing, but after scouring the warehouses and docks of Savannah he found a sack full of raw cotton still on the seed. Miller gave Whitney a room in the basement of the house and he set to work with such tools as he found or could make, drew his own wire and in a few weeks had a working model which left no doubt of success. The cotton gin, as the machine came to be called, is almost the only major invention which is clearly the work of one man, evolved by him in a few weeks, and containing from the start all the essential elements of the invention in their final relationship. The modern gin is larger, stronger, better designed and better built, but it is essentially the same machine as the first one Whitney made in the workshop on Mrs. Greene's plantation.

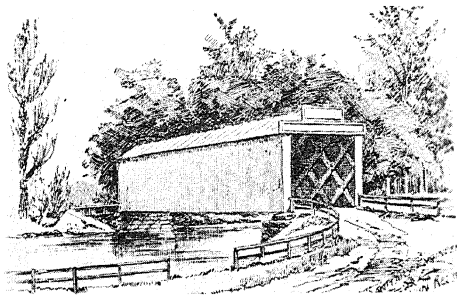
The invention consists of three main elements:

(1) A receptacle for the raw cotton, that is, fiber with the seeds still attached. At the bottom of this are numerous slots narrow enough to preclude the passage of any seeds.

(2) A series of forward-pointing teeth or sharp prongs mounted upon a revolving cylinder. During their revolution these teeth pass through the slots, catch the fibers, tear them from the seeds, and carry them through the slots, leaving the seeds behind.

(3) A revolving brush, moving faster than the teeth and in the same direction. The brush wipes past the teeth and cleans them, throwing the clean fibers into another receptacle.

When the fibers have been cleaned from seeds, the seeds are removed and replaced by a fresh lot of raw cotton.



Ithiel Town's Truss Bridge across Lake Whitney at Davis Street, as it appeared, 1860-1891. From W. P. Trowbridge's article "Town's Truss" in Columbia University School of Mines Quarterly, July, 1888.



Courtesy of Center Church, New York

Ithiel Town (1784-1844), from a portrait by F. R. Spencer, 1839.

A little later Whitney made several models of this first gin. Two are now in the Smithsonian Institution in Washington. One was in the Patent Office and was lost when the office was burned in 1836, and one was in the possession of the Whitney family. This last has been placed by them with the New Haven Colony Historical Society, and is one of their most treasured possessions. It can be seen by anyone here at any time and is well worth a visit.

The effect of this invention was immediate and almost unbelievable. In 1785 several bales of cotton were seized by the customs authorities at Liverpool on the ground of false declaration; it was believed they could not have been grown in the United States. In 1791 the United States produced only 1/245 of the world's cotton; of this it exported 189,000 pounds. In the next year, 1792, it exported 138,000 pounds, an actual shrinkage of 51,000 pounds. Whitney invented the cotton gin in the winter of 1792-1793. In 1793 we exported 487,000 pounds; in 1794, 1,601,000 pounds; in 1795, 6,276,000 pounds; in 1800, 5 years later, 17,790,000 pounds. By 1845 the United States was producing nearly seven-eighths of the world's supply. At present the annual production of cotton in the United States for domestic use and export is about 7 billion pounds. With the exception of a negligible amount of Sea Island cotton, all of this vast production has been made commercially possible by Whitney's cotton gin. Measured by its economic effects it is one of the world's major inventions. It made available the raw material for the cotton manufacturers throughout the world, and changed cotton goods from a luxury article to the poor man's fabric. Its political effects were as far reaching. Cotton became King, dominating our political life for two generations and leading to the Civil War.

How did the inventor and the creator of all this fare? Most of the great inventors have had a hard struggle to have their work accepted. Here we find an amazing reversal. With the cotton gin the success was so overwhelming that it almost immediately got out of control. An invention can be so valuable as to be worthless to its inventor. As Whitney, in his clear-headed way, put it to Fulton, when the latter was in a similar struggle, "I should have had no difficulty in causing my rights to be respected if it [the invention] had been less valuable. . . . At one time, few men in Georgia dared to come into Court and testify to the most simple

facts within their knowledge relative to the use of the machine. In one instance I had great difficulty in proving that the machine had been used in Georgia, although at the same moment there were three separate sets of this machinery in motion, within 50 yards of the building in which the court sat, and all so near that the rattling of the wheels was distinctly heard on the steps of the court house."

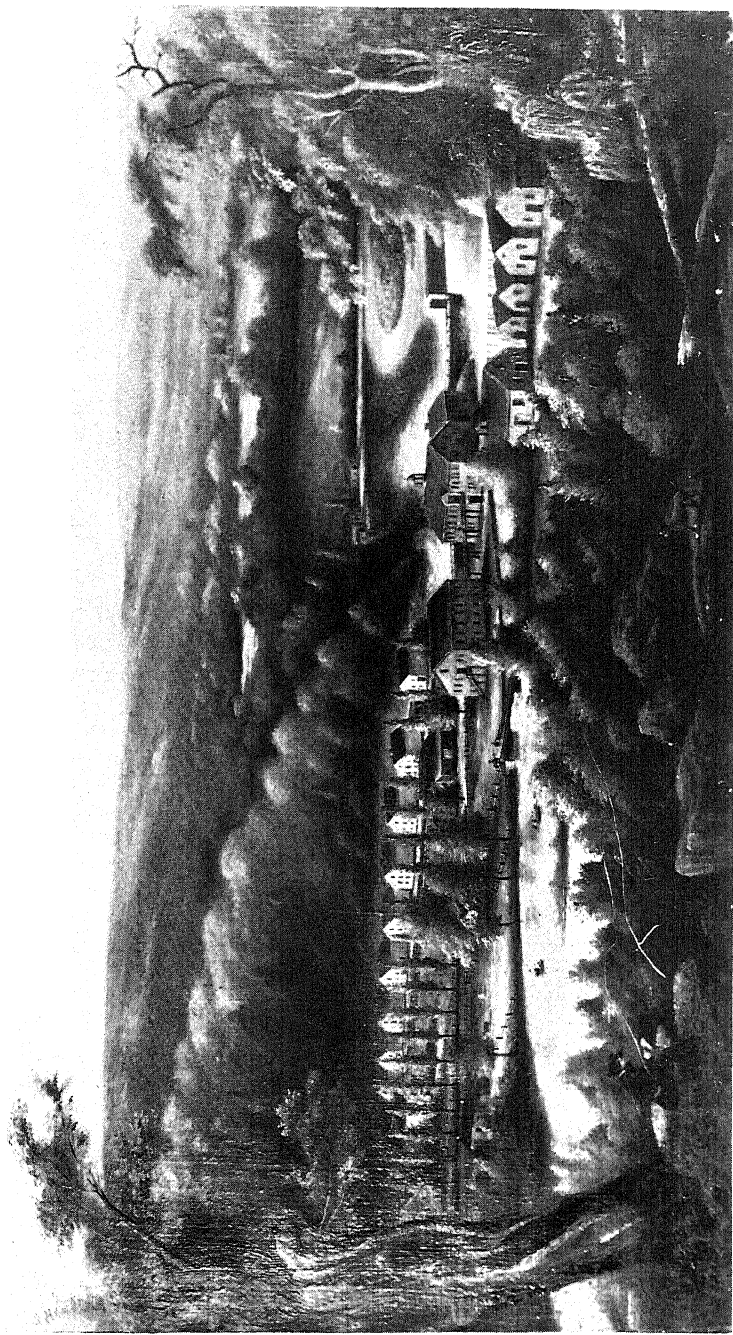
Whitney joined with Phineas Miller to form the partnership of Miller and Whitney. Their original plan was to build and operate their own machines, buy the raw cotton, gin it themselves, and sell the clean staple. This policy involved two fatal defects. The first was that Miller and Whitney could not supply gins fast enough, and infringing ones sprang up everywhere. The second one was that they had to finance the cotton crop. When they realized the situation they changed their plan, but it was then too late.

After long and costly litigation the patent was finally sustained in a famous decision by Judge Johnson, but by that time it had only a few years to run. Because of this Whitney made application for an extension; but southern political pressure forced a rejection of the application. In all, Whitney received from various sources about \$90,000, but the more than sixty suits to establish his rights cost him practically this amount, so that all told he about broke even, for an invention that has enriched half the world.

Few great inventors have been as clear-headed as Whitney, or as good business men. Recognizing that he would never make much profit from the cotton gin, he turned to the manufacture of an unpatented article by a new method, and died well off. In so doing, he affected modern industry as profoundly as he did with the cotton gin. Most intelligent persons know that Eli Whitney invented the cotton gin. Few realize that we owe chiefly to him the modern system of interchangeable manufacture.

When the Revolution closed there were no factories in this country for the manufacture of military fire-arms. Individual gunsmiths were making sporting guns, some of them famous, like the old Kentucky long-barrel rifles, but nowhere were muskets or pistols produced in quantity. This shortage was acutely felt during the Revolutionary War when France was almost our only source for arms.

Under a contract dated June 14, 1798, Whitney undertook to sup-



The Whitney Armory from a spur of East Rock. From a painting by a local artist, William Giles Munson, during Whitney's time; showing the workmen's cottages, the levee dam and Torrey's bridge in its original location.

ply for the United States Government 10,000 muskets of the Charleville pattern at \$13.40 each. He had to give a bond of \$30,000 for the performance of the contract. Ten of the most responsible men in New Haven gave security for a loan to enable him to begin the work. Among these were names familiar in New Haven to this day—Simeon Baldwin, David Daggett, Pierpont Edwards, Jeremiah Atwater, James Hillhouse. This action was a significant tribute to Whitney when we remember that he was then only six years out of college. He purchased land for a mill site and built an armory at Whitneyville, utilizing power from a low dam which was replaced in 1860 by the high dam that forms the present Lake Whitney. It was "the most respectable private establishment in the United States for carrying out this important branch of business." It was commenced and carried out "upon a plan unknown in Europe, the object of which was to substitute the operations of machinery for the skill of the artist." The aim was "to make the same parts of different guns, as the locks for example, as much like each other as the successive impressions of a copper plate engraving." In other words, this was the start of interchangeable manufacture, an undertaking requiring foresight and amazing courage.

While the advantage of interchangeability in military arms was obvious and well recognized, no one at that time thought it practical or even possible except at prohibitive cost. Every gun, they said, would have to be a model and there were not enough skilled workmen to execute the work. Whitney's answer was, instead of building each gun separately, a division of labor, putting the parts through in lots, and the transfer of skill in mechanical operations to tools and machinery. In 1801 Jefferson wrote to Madison that Whitney had "invented molds and machines for making all the pieces of his locks so exactly equal that, take 100 locks to pieces and mingle their pieces, and the 100 locks may be put together by taking pieces which come to hand." Whitney later stated that "it was the understanding that the manufactory should be established on this principle and it has been pursued from the beginning."

It is only fair to state here that Simeon North in Middletown undertook a contract for 500 pistols for the Government the following year and that soon—how soon we do not know—he too was well started on manufacture involving subdivision of labor and

standardization of parts. He followed this with other contracts in 1800, 1802, 1808, 1810. In 1812 Whitney obtained a second contract for 18,000 muskets and in 1813 North one for 20,000 pistols. This last contract contained the following significant clause: "the component parts of the pistols are to correspond so exactly that any limb or part of one pistol may be fitted to any other pistol of the 20,000."

This seems to be the first contract definitely specifying interchangeability. However, it does not mark the beginning of the system but rather the first contractual recognition of a practice that had already come into use. By this time interchangeable manufacture was well established in both of these shops. While there is some uncertainty, the priority seems to lie with Whitney. There can be no question however that Whitney had the greater influence in establishing the interchangeable system throughout the country. North was little known. Whitney was famous through the invention of the cotton gin, while his armory was the largest and best equipped in the country. It was to him that the Government turned for help in establishing its own armories in Springfield and Harper's Ferry. It was he who influenced Eli Terry to apply the system to the manufacture of wooden clocks. Later one of Terry's workmen, Chauncey Jerome, applied it to rolled brass clocks.

After Colt's unsuccessful venture in Paterson, N. J., he turned to the Whitney armory and they manufactured his revolvers for several years. When Colt determined to build his own armory at Hartford he planned from the start to embody the principles of interchangeable manufacture in their most advanced form. As new inventions arose adapted to this system they utilized the tools and methods developed by the gun makers. So there can be little challenge that the cradle of interchangeable manufacture was the Whitney armory, within two miles of where we are now.

During his life Whitney was continually devising new tools and methods which spread elsewhere. The milling machine, one of the most important types of machine tool, can be clearly traced back to him. In the 1913 edition of the *Encyclopedia Britannica* is the statement that the "very first milling machine was running in a Connecticut gun shop in 1818." I tried to check this up with the late Eli Whitney, grandson of the inventor. Mr. Whitney

thought a moment and replied that so far as he knew that must refer to the old Whitneyville armory, and after a pause he added "and I think that machine is still in existence. If it is, it has been in a haymow in the Water Company's barn for 26 years." He said that there was a little old machine which he remembered from his boyhood as a worn-out discard long before the Civil War. It was stuck off in a corner of the shop, but the old workmen would not let anyone touch it because they said it was his grandfather's first milling machine. Mr. Whitney had salvaged it as it was going into the scrap heap when the plant was taken over by the Winchester Repeating Arms Company in 1888. He had it taken over to the Water Company's barn, which then stood across the street. It was put in a stall, later covered with hay and lay there undisturbed until Mr. Whitney remembered about it. It was brought to light; for some years was in the Mason Laboratory, and is now in the New York Museum of Science and Industry at Rockefeller Center. Without doubt this is the oldest milling machine in existence. Unhappily, it is the only tool of the early day that has survived. The evolution of the milling machine can be traced quite clearly from this tool down to the Lincoln miller and other types of production milling machines of today.

It will interest a New Haven audience to trace the history of this old plant. Eli Whitney married in 1817. His health began to fail in 1823, and he died in 1825, leaving one son, Eli Whitney, 2nd. During the latter's childhood the armory was run for ten years by Philos and Eli Whitney Blake, two nephews of Eli Whitney. From 1835 to 1842 it was run by ex-governor Edwards, executor of Whitney's estate. In 1842 the direction was taken over by Eli Whitney, 2nd, who had graduated from Princeton the year before.

If it were not for his father's great reputation, Eli Whitney, 2nd, would be much better known. He was a leader in the development of guns and gun manufacture for many years. Many patents were taken out by him, either singly or with others, over a period of more than thirty years. He first made gun barrels of steel, and greatly improved the methods of boring and rifling them, and was one of the first manufacturers of percussion-cap guns which replaced flint locks.

Blake's *History of Hamden* states that "when the son took over the armory in 1842 it was run by two 14-foot undershot water

wheels of about 10 horsepower each" and in addition the polishing work was done by "one little flutter wheel." The old dam which drove these wheels was only 6 feet high. The present 35-foot dam, creating what is now Lake Whitney, was built in 1860. This raised the power available to 235 horsepower, produced by three turbines. Whitney Avenue, instead of curving to the west along the lake as it now does, used to run straight north to the Hartford Pike, crossing the old pond at a bridge built by Ithiel Town, which was the first pure truss bridge ever built. The new dam served a double purpose; to supply water for the city and to supply power for the armory. Up to that time New Haven had no regular water supply.

Eli Whitney, 3rd, joined his father in the armory soon after graduation at Yale in 1869, and the armory continued under the management of the Whitney family until it was leased to the Winchester Repeating Arms Company in 1888. They manufactured .22 calibre rifles there for some years. Later still it was taken over by the Acme Wire Company and since that time it has changed hands several times. Several of the buildings that come down from the days of the first Eli Whitney are still standing. Until a few years ago there was a row of small stone dwellings on the north side of Armory Street beneath the steep slope of Mill Rock, that were built by Whitney to house his workmen. These are said to have been the first houses in the country to be built by an employer for his employees.

In person Whitney was a large man, slow moving, kindly and dignified, but without trace of affectation. His clear judgment and integrity gave him commanding influence and he had the respect and affection of all who knew him. He met both success and disappointment early in life without being spoiled by either. Eli Whitney's name still lives in New Haven in the Avenue, the Lake and region about the armory. And well it might, for he was one of the most distinguished of all its citizens and of all the graduates of Yale College. He was a great inventor and an industrial pioneer, who affected modern life profoundly along two wholly independent lines. Whitney died at fifty-nine, well-to-do and deservedly honored. He lies buried in Grove Street Cemetery.

EARLY NEW HAVEN INVENTORS

JOSEPH WICKHAM ROE

VISITING PROFESSOR OF INDUSTRIAL ENGINEERING, YALE UNIVERSITY

INVENTORS here, as in the rest of the country, showed little activity until after the Revolution, when American industry was freed from the restrictions imposed by England. Among the earliest of the New Haven inventors were Buell and Augur.

ABEL BUELL (1742-1822), was a picturesque figure. He got off to a bad start as a counterfeiter, was tried and condemned, but pardoned a few years later. He had a long and checkered career, as a typefounder, die cutter, silver- and gold-smith, engraver, inventor, ship owner, quarryman, and mill operator, to mention only some of his many activities. He invented and built gem cutting machinery, a coin press, and a corn planter. He minted money for the colony; cut and cast the earliest font of Roman type in English America; engraved charts and maps, and incidentally Yale College diplomas. He died in the almshouse, eager, restless, inventive to the very end.

HEZEKIAH AUGUR (1791-1858), also had a strange career. He too was an inventor, but is best known as one of the early American sculptors. He was a store clerk, with indifferent success, and kept a cigar stand; a recluse who invented and carved wood in his off hours. He attracted the notice of S. F. B. Morse and under his influence Augur became a sculptor, with considerable success. It may be interesting at this time to note that he modelled the face of the medal struck in 1838 to celebrate the bicentennial of this city. It represented the preaching of the first sermon here by John Davenport, the composition of the group being quite similar to that of the stained glass window in Center Church. Among his inventions was a carving machine which attracted wide attention at the time; a model is now with the New Haven Colony Historical Society.

As Whitney Avenue approaches Lake Whitney it curves up past the present dam and rises to the level of the lake. One hundred years ago there was a low dam there, about 6 feet in height, and the

slack water above it reached only a little way upstream. Whitney Avenue, instead of curving as it now does, thus ran straight northward into the Hartford turnpike, crossing the stream on a covered wooden bridge which is believed to have been the first pure truss bridge. It was designed by ITHIEL TOWN.

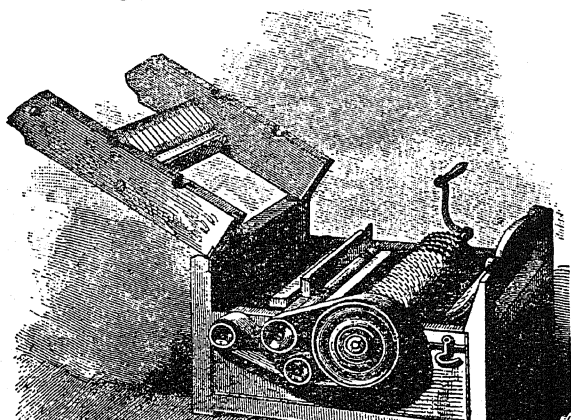
He was born in Thompson, the northeast corner town of Connecticut, in 1784. The son of a farmer, he had little schooling, but he had a scholarly mind and refined tastes. He worked first as a house carpenter near his home and then went to Boston, working there and studying under Asher Benjamin.

Town's fame as an architect was made on the Center Church here in New Haven, designed and built by him in 1812-14, when he was less than 30 years old. The spire of this church is one of the finest examples of early American architecture. The building of it shows Town's capacity as engineer as well as architect. The lovely wooden spire was built, from the ground up, in a vertical position inside the brick portion of the tower and when finished was raised "by an ingenious windlass and tackle" to its present position in less than two and a half hours. This had been done at least once before, about 40 years earlier, with the spire of the church in Farmington; there, however, the spire was much smaller, and the engineering problem simpler. I might add, also, that Henry Austin, a pupil and great admirer of Town, attempted to do this same thing with the spire of the church in Danbury. When it was within three or four inches of its prepared place, one of the guy ropes broke and the spire crashed through the roof and cornice of the church. The wreckage was cleared away and the spire was rebuilt in the conventional way. The Center Church spire is 210 feet high. The successful raising of such a weight under such delicate conditions was a creditable piece of engineering. We can fancy that the Green was fairly crowded while the operation was going on. A year later Town built nearby Trinity Church, and still later the old State House, now gone.

The success of Center Church made his reputation and for more than 30 years Town was one of the foremost American architects, building state capitols, many churches and other buildings throughout the country. He was one of the first ten selected, in 1826, to form the National Academy of Design, and the only architect in that first group.



Eli Whitney (1765-1825). from a portrait by S. F. B. Morse, 1822, presented to Yale College, 1827.



In 1820 Town took out a patent on a new type of bridge which was the first successful truss. It was a pure truss in that it was a self-contained structure that rested merely on the piers without the end thrust characteristic of the arch. The Whitneyville bridge built in 1823 was the first of this type. Its construction followed that shown in the patent drawings and in a pamphlet published by him in 1821. It had 100 feet clear span, and side bracings of 3-inch planks crossing each other at an 80-degree angle and spaced 4 feet center to center. These were securely pinned together and held top and bottom by stringers on each side which measured 12 inches by 5½ inches. The pins or "trunnels" were 2¾ inches diameter, made of oak and wedged at each end. There was no mortising of the timbers anywhere. Pin connections only were relied upon. The bridge was symmetrical vertically and would have been equally strong if turned upside down. It stood in its original place for 37 years until 1860, when it was lifted bodily from its abutments and moved, under the direction of Eli Whitney, 2d, a quarter of a mile upstream and set unharmed upon new abutments in the place now occupied by the present bridge. It is said that this removal was done at a cost of \$250. The bridge continued in service until 1891 when it was replaced by a steel one, which in turn is shortly to be replaced.

The Town truss or lattice truss, as it came to be called, was peculiarly well adapted to American pioneer and rural conditions and was widely used for highways and early railway bridges. One of these bridges, a railroad bridge across the James River at Richmond, had 13 spans and was 2900 feet long. There were other long bridges across the Susquehanna, the Hudson, and other streams throughout this country, Canada and in Europe. One of the reasons for its wide use was the fact that it contained little or no iron work, called for ordinary planking, had no mortises and tenons in the construction and therefore could be erected from materials available everywhere, by ordinary carpenters. One bridge of 200-foot span, which was 120 feet above a river bed, is said to have been erected by local labor in two weeks. While the design was especially well adapted for timber construction, it was utilized also in some early iron bridges. Aside from his standing as an architect, Town became the best known bridge builder in the country at this time and his royalties of \$1 per foot span gave him a comfortable income for the rest of his life.

Although he maintained an office in New York and an agency in Washington, Town built a house in New Haven and made it his home the rest of his life. He died here and lies buried in Grove Street Cemetery. The home which he designed and built for himself is the brown-stone house on Hillhouse Avenue opposite St. Mary's Church, afterward sold to Joseph Earl Sheffield and now a part of the Sheffield Scientific School. It was added to and greatly changed, much to its detriment, after Town's death. It contained a large library, 45 feet long, 25 feet wide and two stories high, which housed the largest and finest collection of choice books on architecture and the fine arts in the United States. In addition there were 170 paintings, mosaics and other works of art. Town spent 30 years gathering this collection here and abroad, where he traveled for two years with S. F. B. Morse. He was generous in the use of its facilities and it was freely open for students of art. Although it was broken up at his death, it was a forerunner of the Yale School of Fine Arts later established by Augustus R. Street.

Ithiel Town's fame is secure. As an engineer he advanced the art of bridge building and gave us an entirely new type of bridge widely used here and abroad. As an architect he represented American taste at its best. He needs no monument in this city, for the throngs which daily pour past Center Church need only lift their eyes to its spire to see a monument nobler than any that others could raise in his honor.

CHARLES GOODYEAR's life is another kind of story. Here was a man always frail, desperately poor, who through years of discouragement, elusive success and repeated failures, made, single-handed, one of the major industrial discoveries, and gave us a material which enters daily into the life of everyone.

Charles Goodyear was born here in New Haven in 1800, fifth in direct descent from Stephen Goodyear, one of the founders of the colony and its deputy governor for 15 years. He had his schooling here but could not afford to go on to college. Instead he went at 17 to Philadelphia and worked in a hardware store for four years, then returned to New Haven to join his father, Amasa Goodyear, in his small hardware manufacturing business. After a few years with his father he went back to Philadelphia and opened a store of his own. For 10 years he struggled along, sink-

ing deeper and deeper financially, repeatedly in jail for debt, and finally was closed out in bankruptcy.

On his way back to New England in 1834 he chanced to examine the valve on a rubber life preserver that he saw in a shop window in New York. He had a talk with the manager and said he could improve upon it. The man listened to him in a friendly way and then told him that even if his proposed valve were all he claimed it was it would do no good; that life preservers made from the newly introduced rubber were worthless because they melted in summer and stiffened and cracked in winter. "Young man, if you want to make a fortune, invent a method of treating India rubber so that it will not stick, instead of wasting your time on life preserver valves." This chance encounter determined Charles Goodyear's life work.

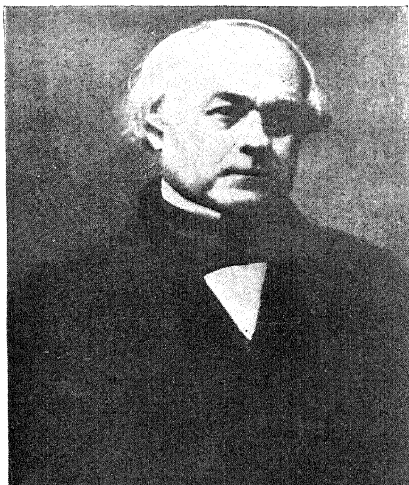
Caoutchouc, or gum elastic, is said to have been brought to Europe from South America by Columbus. For 300 years no use was found for it until Priestley started its use for erasing lead pencil marks. This re-christened the material as "rubber." No further use was found for it until about 1820 when Charles MacIntosh, a Scotchman, began to waterproof cloth with it for raincoats, and added another word to the English language. About the same time a Frenchman began to use it for elastic tapes and garters. In 1821 about 500 pairs of India rubber shoes were imported into Boston. They were made by South American natives, who collected the latex and dipped into it a clay last covered with a white powder to keep the rubber from adhering to it. This was held over a smoky fire to dry. As each coating became hard enough, another was added and smoked. When the desired thickness had been obtained the work was dried in the sun and the form broken out. When ready for market the shoes were stuffed with grass to keep their shape and then shipped. They were thick, heavy and ill-fitting, but the business increased rapidly and enterprising men thought they saw a good business in importing crude "gum elastic" and making shoes here by more efficient methods.

An active manufacture sprang up around Boston, which was a sort of South Sea Bubble. They launched into all sorts of rubber cloth goods, boots, life preservers, and the like. But trouble soon developed. The gum elastic was tricky to handle and unstable, and did not adhere satisfactorily to the fabric. Rubber goods on store

shelves frequently stuck together and became a total loss. Within a few years all the new companies were bankrupt and closed. Until some satisfactory method of curing or "tanning," as they called it, was invented, rubber goods could never have any economic importance. This method was supplied by Charles Goodyear.

It was, however, years before he found the answer to his problem. When he started he had no knowledge of chemistry, but he was a tireless experimenter, a keen observer and nothing escaped him. Few inventors have labored so long against such ridicule or in direr poverty. He worked in sheds, in his own kitchen, in abandoned rubber factories, wherever he could find space. His first flicker of success came when he mixed in some magnesium salts and boiled the mixture in weak lime and water. With this he was able to make thin sheets that had a hard smooth surface and seemed satisfactory. So he took out a patent on the process. But it soon developed that any common acid such as cider or vinegar would ruin it. He therefore turned again to his ceaseless experimenting. He believed that what was hidden and unknown would "most likely be discovered by accident, if at all, and by the man who applied himself most perseveringly to the subject, and was most observing of everything related thereto." One of the accidents he was looking for came when he tried to wash off some ornamentation from a piece he was working on with nitric acid. This darkened the gum and he threw the piece away as spoiled. But something about the feeling of it made him return to it a day or so later, when he found that it was cured. Following up this lead he developed and patented the process by which he could successfully treat *thin* sheets. These found a ready market; he found financial backers in New York and seemed started toward success. Then the panic of 1837 ruined them and Goodyear was again desperately poor. He pawned everything he had, still keeping on with his experiments, and was looked upon as a monomaniac. People said "If you see a man with India rubber coat, India rubber shoes, India rubber cap, and in his pocket an India rubber purse with not a cent in it, that is Charles Goodyear." He returned to New York and began the manufacture of overshoes, with some success.

Meantime a friend, Nathaniel Hayward, who had been a foreman in one of the closed rubber factories, found that by combining



Courtesy of Arnold G. Dana.

Chauncey Jerome (1793-1868).



Charles Goodyear (1800-1860), from B. K. Peirce's "Trials of an Inventor." New York, 1866.

sulphur with the gum and exposing it to sunshine, a satisfactory *surface* was obtained. He patented the process and sold it to Goodyear, who branched out on a new venture. But it soon developed that this process, too, was effective only on thin sheets. When he tried to manufacture articles like mail bags and life preservers of thicker material, they came back to him an ill-smelling mess. But he still kept on doggedly. Hayward's sulphur-solarization process was a step in the right direction, but only a step. There remained a vital element to be added—sufficient heat.

During some experiments in his own kitchen on the sulphur-impregnated compound that had decomposed in the mail bags, some of it fell on to the hot stove. His keen observation noted that it charred rather than melted. With brilliant intuition he jumped to the inference that if the charring process could be stopped at the right point it might give what he sought. Further trials with partial charring always showed a line or border that had escaped charring and was perfectly cured. He was now on the right track but there still remained many months, determining the factors involved, the right amount of sulphur, the right degree of heat, and the right rate and method of application, until he finally mastered the process we now call vulcanization, which he patented in 1844. In vulcanization Goodyear had found much more than he had originally sought. He had started out to improve the qualities of gum elastic, but he had created what was in effect a new material, useful for many purposes of which he had not even dreamed; a material that could be made soft and elastic or hard and capable of high polish, and one of the best of electrical insulators.

Goodyear published in 1853 a book on "Gum Elastic and Its Varieties with a Detailed Account of Its Application and Uses." A number of copies were printed on rubber instead of paper. Nothing shows better than does this book, irrespective of its contents, how far beyond his original objective he had gone. A review of the book said, "The India rubber covers resemble highly polished ebony and the leaves have the appearance of ancient paper worn soft, thin and dingy by numerous perusals. The volume contains 620 pages; but it is not as thick as copies of the same work printed on paper, though it is a little heavier. It is evident that the substance of which this book is composed cannot be India rubber in its natural state. These leaves, thinner than paper, can be

stretched only by a strong pull, and resume their shape perfectly when they are let go. There is no smell of India rubber about them. We first saw this book in a cold room last January but the leaves were then as flexible as old paper, and when, since, we have handled it in warm weather, they had grown no softer. . . . The book itself tells us that it can be subjected, without injury, to tests more severe than summer's sun and winter's cold. It can be soaked six months in a pail of water, and still be as good a book as ever. It can be boiled; it can be baked in an oven hot enough to cook a turkey; it can be soaked in brine, lye, camphene, turpentine, or oil; it can be dipped into oil of vitriol, and still no harm done. To crown its merits, no rat, mouse, worm, or moth has ever shown the slightest inclination to make acquaintance with it." Some reviewers seem provided with lye, vitriol, boilers, and hot ovens. Here is a book which might have baffled even them.

It was more than a curiosity in the printing art. It is a remarkable story, told in the first person without a trace of conceit. The author frankly recounted his failures, his false hopes, his finding the answer he had sought for so many years. He revealed the spirit of the inborn inventor, caring little for money and centering his whole life on mastering an obstinate material and rendering it useful to mankind. This objective was for him little less than a religion.

Goodyear's invention long played an important part in New Haven's economic life. Leverett Candee, his first licensee under the vulcanization patent, with his associate, Henry Hotchkiss, established the L. Candee & Company Rubber Boot and Shoe Works in 1846, which has employed at times more than 1500 people. It was the first and at times the largest footwear manufacturing plant in the world and one of the companies around which the United States Rubber Company was organized in 1892. The Seamless Rubber Company is another New Haven industry whose activities are built upon Goodyear's basic invention.

With his ceaseless exploring into every possible use to which rubber could be put, it is strange that Goodyear missed entirely the use that now absorbs more than three-quarters of the rubber produced in the world; namely, vehicle tires. Apparently he never suspected that rubber had greater wearing qualities for road use than steel. This seems to be almost the only use Goodyear missed.

In our consideration of Eli Whitney it was pointed out that the cotton gin was almost the only great invention clearly the work of one man. Goodyear's is another, but with this difference. Whitney's invention was completed in a few weeks. Goodyear's took years of cruel struggle, but resulted in an equally great achievement. Practically all our basic materials such as iron, the useful metals, glass, pottery, leather, cement and paper, have long been known. One, however, commercial rubber, is not yet a century old and we owe it to Charles Goodyear.

Another inventor whose work has resulted in one of the major industries of this city is CHAUNCEY JEROME.

Clock making as a handicraft was widespread through all the northern colonies. Mr. Hoopes tells us there were not less than 100 clockmakers scattered throughout Connecticut during the 18th Century. As the towns were small and transportation poor, metal supplies were expensive and difficult to obtain, and manufacturers used such materials as were available. The wooden clock therefore seems to have had its American origin and practically its entire development in Connecticut. These old wooden movements, including hands, dials and weights, were peddled by their makers for from \$15 to \$25. Brass clocks were rarer and more expensive, for the movements cost as much as \$50, without case. Usually the cases were supplied separately by local cabinet makers and cost \$30 to \$50.

The first of the two men who led in the development of clock-making from a handicraft to a manufacturing industry was Eli Terry, who had worked with the best of the Colonial clockmakers, Daniel Burnap. At first Terry made and peddled the wooden movements in the old way. In 1802 or 1803 he started to make them in quantity and let others do the peddling and, influenced by Eli Whitney, he began making the movements by machinery. In 1807-8 he undertook to make 4000 movements and completed the contract in three years. In 1814 Terry invented the 30-hour shelf clock, patented in 1816, which revolutionized the clock business and was produced in great quantities for many years; in fact until superseded by brass clocks. These were at first sold for about \$15 and finally for about \$5.

One of the men who worked for Terry in this transition from hand to machine production was Chauncey Jerome. He was born

in Canaan in 1793, son of a blacksmith and nail-maker. He started work for Terry in 1816, building and installing his machines for making movements and later cases, one of these machines being a power driven circular saw which was considered a great curiosity. He became thoroughly familiar with Terry's practice so far as wooden movements were concerned. In 1825 Jerome brought out a bronze looking-glass clock case which began competing with Terry's. Meantime Joseph Ives began to make an eight-day brass clock selling for about \$20. Wooden clocks were cheaper and were good timekeepers, but had certain disadvantages which led ultimately to their disappearance. The very name "wooden" was a handicap abroad and was associated with wooden nutmegs. They could not stand extreme dampness, for the wooden works swelled and became useless. In 1837 Jerome developed the idea of a 30-hour brass clock that would be cheaper than an eight-day brass clock and both cheaper and better than a 30-hour wooden one. With his brother, Noble Jerome, he began its manufacture, using and carrying still further the methods which Terry had employed for wooden works. He steadily improved his methods of machine production until his clocks were made at a cost of less than 50 cents and later were being produced at a rate of 400,000 per year. In 1841 Jerome made \$35,000 clear profit.

In 1842 Jerome began to export clocks to England. When he sent his first consignment to Liverpool it was confiscated by the customs authorities for undervaluation. The penalty for this at that time was to take over the goods at the declared value plus 10 per cent. This was done and the clocks were paid for in cash. Another and larger consignment which soon followed shared the same fate. This looked good to Jerome back in Bristol. Here was a spot cash buyer with no selling expenses. When a third and still larger lot arrived, still declared at the same price, the customs authorities let it in and retired from the clock business. But finding real purchasers in England was not so easy and Jerome encountered a stone wall of prejudice. Both dealers and customers said, "The clocks are good for nothing or they could not be offered so cheap." But the sale once started spread rapidly and developed into an important business.

In 1844 Jerome bought a bankrupt carriage factory here in New Haven and began making cases for his movements which were still

made at his first two factories in Bristol. In April 1845 the larger of the Bristol factories burned and nearly 70,000 movements were lost. It was a staggering blow to Jerome. People had ridiculed him anyway for coming to New Haven to manufacture by steam power, and now said that with this loss he was through. But he enlarged his New Haven plant and brought his Bristol movement makers down here, and was soon going again stronger than ever.

In a book which Jerome published in 1860 he gives an account of some of the methods and costs at that time. The cost of labor was reduced to about 20 cents per clock. He could sell a clock for 75 cents and make a fair profit. He put through the parts for cases in 10,000 lots. His dials were stamped by machinery; the letters and figures were printed upon them. Three men could make and cut all the wheels for 500 movements in one day.

Although Jerome was not a great inventor, he was one of the most skilled manufacturers New England has ever produced. And yet he was not a good business man. His financial ups and downs are amazing. Time and again he lost heavily through misplaced confidence and inability to judge men in financial transactions. In 1850 he induced Benedict and Burnham to join with him to form the Jerome Manufacturing Company, with a stock of \$200,000. This concern was highly prosperous for some years but over-extended its operation and in 1855 made the mistake of buying out a Bridgeport clock manufactory controlled by P. T. Barnum. This transaction proved fatal to the Jerome Manufacturing Company and to Jerome's personal financial interests. The Jerome Manufacturing Company assumed the obligations of the Bridgeport company, which proved to have been grossly understated, and the value of its inventory as disproportionately overstated. The result was that the Jerome Manufacturing Company became bankrupt within six months.

The property and business were taken over at a valuation of \$20,000 by a group headed by James English, H. M. Welch, John Woodruff, Hiram Camp, and L. F. Root, who two years earlier had formed the New Haven Clock Company. As the crash of the Jerome company had been precipitated by high finance and not by poor methods or business depression, the merged company was soon prosperous and has so continued until this day. In 1860 Jerome listed five companies in Connecticut with a combined out-

put of about 500,000 clocks per annum, of which the largest, the New Haven Clock Company, made about 200,000.

In this debacle Jerome, at the age of sixty-three, lost everything. It was doubly bitter for him as he was mayor of the city at the time. He went back first to Waterbury and then to Ansonia, trying to get onto his feet, and again lost much through misplaced confidence. He finally moved back to New Haven and died here in relative obscurity in 1868. The business which he started here in New Haven was the largest in the city at that time and an important element in the rapid growth of the city. In 1840 the population of New Haven was only 14,000; in 1860 it was 44,000. Jerome's book is an interesting human document, but it is probably subject to considerable discount. Much of it is taken up with an account of his troubles and how he was done out by rascals all through his life. But when all allowances are made, he played a leading part in the economic development of this city and of this state, and gave the world a needed article at prices which put it within reach of all.

HIRAM CAMP was a nephew of Jerome. He began working for him when 18 years old and became his right-hand man. He supervised the building and installation of the new machinery when Jerome moved to New Haven, and continued as his superintendent. Camp went into business for himself in 1851 and organized the New Haven Clock Company in 1853. As we have seen, when the Jerome Manufacturing Company crashed in 1855 the New Haven Clock Company bought the wreckage, took over the business, and became the largest clock manufacturing enterprise in the world. Camp was president of it for many years; in fact until within a year of his death. He was prominent in public life, a leader in religious work, and one of the founders, with Dwight L. Moody, of the schools at Northfield and Mount Hermon.

LAUREN F. ROOT was another of those who came down from Bristol and became prominent not only in the company but in the life of the city.

From the time of the Revolutionary War, New Haven has been the home of inventors who have contributed much to the life of the city. Some, like Whitney and Goodyear, are world famous. Others, less widely known, have, through basic inventions, made whole industries possible. Such a man was Eli Whitney Blake, whose stone

crusher made possible the wide use of concrete, a material known from the time of the Romans, but relatively unimportant until Blake's invention provided means for breaking stone in sufficient quantities and at economical costs. Others were Edward Beecher and Thomas Sanford with their inventions in match-making machinery; Henry S. Parmelee who made the basic invention in automatic sprinklers, and Joseph Parker, inventor of blotting paper.

The Winchester Repeating Arms Company and Sargent and Company are New Haven's largest industries. Oliver F. Winchester and Joseph B. Sargent, who founded them, were outstanding men, but they were prominent rather as manufacturers and business men than as inventors. Both companies have, of course, acquired and produced from within their own organizations many inventions. But few of these have been basic. They have been important for their cumulative effect rather than for the influence of any single one.

To the many other inventors too numerous to mention here whose ingenuity and skill have contributed to the growth of the city's manufacturing industries we owe a debt that can never be paid. A century ago New Haven was scarcely more than an overgrown town. It took 200 years for the population to pass the 10,000 mark. The growth and prosperity of the city in this third century now closing is due in almost as great degree to these men as to those more widely known.

EARLY YALE INVENTORS

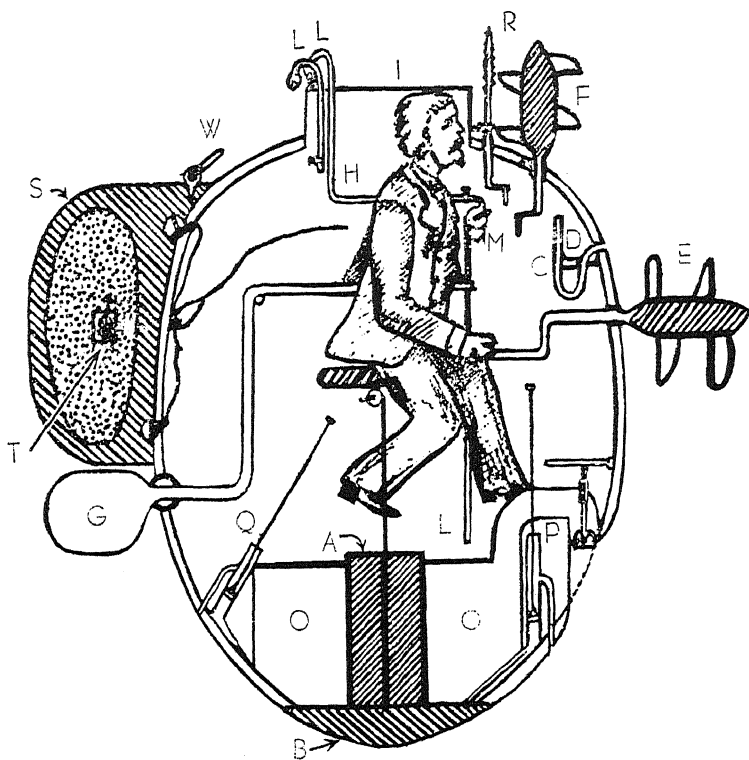
RALPH HENRY GABRIEL

LARNED PROFESSOR OF AMERICAN HISTORY, YALE UNIVERSITY

EVER since a peculiar national civilization began to form in the eighteenth century, American culture has been distinguished for the practical inventions which it has produced. Benjamin Franklin, Massachusetts *émigré*, who spent most of his life in Philadelphia, illustrated perfectly this trait of the American mind. He was interested in the laws of nature in order that he might make them useful to men. He studied optics and invented the bifocal lens. He observed the ways of heat and created the iron stove. He pioneered in observations on the weather and began the work which ultimately took form in the United States Weather Bureau. His greatest scientific work, recognized in his day as one of the most brilliant intellectual achievements of the eighteenth century, was to demonstrate in his famous kite experiment that electricity moves. Franklin immediately gave practical application to his discovery with an invention, the lightning rod. Yale College, in giving Franklin an honorary degree, acclaimed not only a man of letters and a statesman but the greatest scientist and inventor west of the Atlantic. In awarding the hood to the great Philadelphia philosopher in 1753, Yale, in effect, announced her conviction that science and invention must go hand in hand with religion in the creation of a worthy and elevated national civilization.

As the decades of the eighteenth and nineteenth centuries succeeded one another American inventiveness produced an ever-increasing number of new machines to lighten or to make more effective the labors of men. The clumsy wooden plow was replaced about 1825 by its cast-iron successor. For this Thomas Jefferson, Virginia planter, supplied the principle for a mould board which would turn the furrow upside down. Another Virginian, Cyrus McCormick, was one of the two inventors of the reaper which, with the metal plow, revolutionized American agriculture and established that foundation of a sound husbandry upon which American

industrialism so securely rests. John Fitch and Robert Fulton produced the steamboat. Though inventors were to be found in every state, New England bred the largest company. Perhaps its stony hillsides, which broke the farmer's plow-points, lamed his back, and provided exercise for his moral qualities, had something to do with this phenomenon. Whatever the cause, in the southern part of that area inventions proliferated in the late eighteenth and early nineteenth centuries until the term, Yankee notions, became nationally famous. Gadgets of tin and wood of bewildering variety were manufactured in Connecticut, in Rhode Island, and in Massachusetts. These were distributed throughout the nation by that most picturesque of early American types, the tin or wood peddler. From the western frontier to the southern plantation New Englanders acquired a reputation for the fertility of their inventive imaginations and for the astuteness of their business methods. Davy Crockett, half legendary hero of the Tennessee backwoods, presented the irreverent outlander's view of the New England inventor when he described in 1836 a certain Job Snelling from Massachusetts who had set up a shop near the Mississippi River for the dispensing of merchandise produced in his old home. "The whole [Snelling] family were geniuses," said Crockett. "His father was the inventor of wooden nutmegs, by which Job said he might have made a fortune, if he had only taken out a patent and kept the business in his own hands; his mother Patience manufactured the first white oak pumpkin seeds of the mammoth kind, and turned a pretty penny the first season; and his aunt Prudence was the first to discover that corn husks steeped in tobacco water would make as handsome Spanish wrappers as ever came from Havana, and that oak leaves would answer all the purposes of filling, for no one would discover the difference except the man who smoked them, and then it would be too late to make a stir about it. Job himself bragged of having made some useful discoveries; the most profitable of which was the art of converting mahogany sawdust into cayenne pepper, which he said was a profitable and safe business; for the people have been so long accustomed to having dust thrown in their eyes, that there wasn't much danger of being found out."



Prepared from a drawing in Lt.-Col. Henry L. Abbot's "The Beginning of Modern Submarine Warfare under Captain-Lieutenant David Bushnell," 1881.

THE BUSHNELL SUBMARINE OR "AMERICAN TURTLE"

Operator entered boat through elliptical crown *H I* in which were three round windows (not shown) for admitting air. *L, L* were air pipes through which ventilator, *M*, drew fresh air to bottom of craft and discharged used air. Boat was kept upright by permanent lead ballast, *A*, and by movable piece of lead, *B*, which could be dropped to sea bottom as anchor. *B* was a safety device, for, when dropped, boat came to surface. Boat was submerged by filling tanks, *O, O*, which could be emptied by force pump, *P*. Another force pump, *Q*, discharged bilge resulting from leakage. Depth was shown by phosphorescent cork in gauge, *C*, and navigation was by phosphorescent compass, *D*. Propulsion forward and backward was by hand-turning of old fashioned screw, *E*. When in equilibrium vessel could be moved up and down by screw, *F*. Rudder, *G*, was flexible and could be used for sculling. Magazine, *S*, contained 150 pounds of powder and could be attached to a ship's bottom, by wood screw, *R*, to which it was attached by a rope *W* (only partially shown). *T* is clockwork percussion mechanism for detonating torpedo.

DAVID BUSHNELL

One of the earnest, ambitious, and ingenious Yankee inventors of the eighteenth century was a young man by the name of David Bushnell who graduated from Yale College in the class of 1775. The commencement was in September. When President Naphtali Daggett presented Bushnell with his sheepskin, the Revolutionary War was already well begun. Lexington and Concord had occurred in April and Bunker Hill had been fought in June. A rebel horde held a British army closely confined in Boston, in the harbor of which British warships guarded the line of supplies and of possible retreat. Bushnell noted that, although Americans could enlist as soldiers, the struggling colonies had nothing with which to oppose British sea power. So the undergraduate in his senior year turned this thought to a problem that has vastly stimulated the inventive genius of the twentieth century, the problem of how a nation weak in sea power can assail the country which controls the ocean. Bushnell asked the question, how can the great battleship, a floating fortress, be ambushed and sunk by an underwater approach? Before his graduation he seems to have perfected his machine, for one day Tutor Lewis of the College, full of excitement and enthusiasm, dashed off a note to Ezra Stiles, soon to become President of Yale. "*Hic Homo est Machinae Inventor*," exclaimed Lewis, dropping into the then academic vernacular, "*quae ad Naves Bostoniae portu Pulveris pyrii Explosione destruendas, nunc est fabricata et fere perfecta*." Undergraduate Bushnell made a boat which would carry underwater an explosive charge that, when fastened with a screw to the wooden bottom of a man of war, would destroy the ship. Bushnell had originated the ideas of the torpedo and of the submarine.

The test of the Bushnell submarine was made in 1776 in New York harbor, whither a British fleet had come to demand that Americans put an end to their rebellion. In July, while the Admiral Howe was waiting for the Americans to consider his peace offers, Bushnell's turtle slipped into the water on a quiet summer night and made her awkward way toward the flagship commanded by Lord Howe himself. But Bushnell, who had fallen ill, was not the skipper. A substitute, a certain Sergeant Ezra Lee, had been hurriedly trained to take his place. The turtle was perfectly navigable and dirigible, as General Putnam, who anxiously watched

her from the shore, later attested. Sergeant Lee laboriously and successfully brought her under the great *Eagle* riding quietly at anchor. He touched the warship near the rudder and to his dismay found the bottom covered with copper plates which prevented him from attaching the explosive charge to the planks. Instead of moving toward the forward part of the ship he retired, still under water, toward the shore. As he went, he apparently began to contemplate the implications for himself of the fifty cannon on board the *Eagle*. He increased to the utmost the lazy turtle's speed. As he feverishly turned the screw, it occurred to him that the charge of powder he was carrying was a hindrance to his progress. He cast it off and soon beached his craft. A little later the timer detonated the charge and surprised English tars saw a harmless geyser leap from the quiet surface of New York harbor. The first submarine attack upon the British navy had failed.

Bushnell's submarine was a curiosity. But he clearly understood the nature of the problem he was trying to solve and he worked out the principles which have guided all his successors in its solution. The submarine as an effective vessel of war and as an instrument of undersea scientific exploration had to await the development of electrical engineering and of the internal combustion engine. Bushnell was more than a century ahead of his time. He had, however, that rare gift, a creative imagination. He made an impression upon his American contemporaries. There is a measure of justice in that word of praise which Timothy Dwight, former tutor at Yale and Revolutionary chaplain, included in his poem, *Greenfield Hill*:

See Bushnell's strong, creative genius, fraught
With all th' assembled powers of skilful thought,
His mystic vessel plunge beneath the waves,
And guide through dark retreats and coral caves.

SAMUEL FINLEY BREESE MORSE

In 1795, the year after he published *Greenfield Hill*, Timothy Dwight became president of Yale. At once this dynamic grandson of the great Jonathan Edwards sought to drive the demon of infidelity from the college campus where it had flourished under the liberal regime of Ezra Stiles. Dwight was an ardent Puritan who more than once turned the college chapel services into revival meet-

ings. With all his interest in religion, however, he recognized that the day of science was dawning. Two of the three young men whom he made professors were scientists. Benjamin Silliman was a chemist and Jeremiah Day a mathematician and what today would be called a physicist. Timothy Dwight, his three professors, and a handful of tutors comprised in the first decade of the nineteenth century the teaching faculty of the little New Haven college. To this institution, in the autumn of 1806, came Finley, the fourteen-year-old son of the Reverend Jedidiah Morse of Charlestown, Massachusetts, and enrolled as a Freshman.

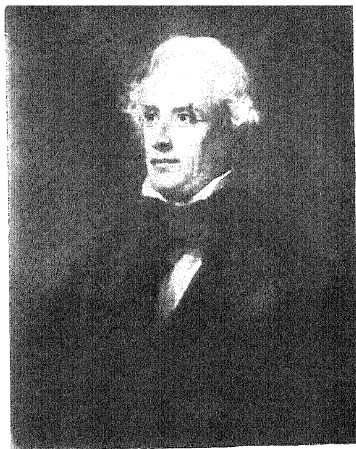
Jedidiah Morse was more than a clergyman. He was the author of the best known book on geography in early nineteenth century America. But neither his literary interests nor the material rewards he derived from his book deflected him for a moment from adherence to that strict Puritan code to which his life was dedicated. "The main business of life," he wrote to Finley at Andover the year before he entered Yale, "is to prepare for death." But he seems to have felt that his offspring was taking his admonition too literally when a year later the young Freshman asked his parent to provide the means with which to furnish his college room with wine, cigars, and brandy. Yale frowned upon brandy, as it did upon card-playing and theatre-going, but the College Butler, from his small stock of goods in a ground floor room of one of the buildings, dispensed along with soap, shoe blacking, quill pens, and paper such warming beverages as cider, beer, ale, porter, and mead. One of the more conspicuous articles of furniture in the president's office, it might be added, was the faculty punch bowl. One suspects that both students and faculty needed warming, for the rooms were heated by fireplaces whose wood was sawed by its users. The chapel, where two sermons were preached on Sundays, was not heated at all. One suffering undergraduate has left a picture of President Dwight preaching on a wintry Sabbath "wrapped in a heavy brown great-coat, with three or four broad capes, and a stout belt closely buttoned around his waist" and with hands protected by woolen mittens.

The chapel which faced the Green stood just south of Connecticut Hall, then known as the Old College to distinguish it from a newer and similar dormitory which had been erected nearer Chapel street. Dwight added to the northern end of this Old Brick Row

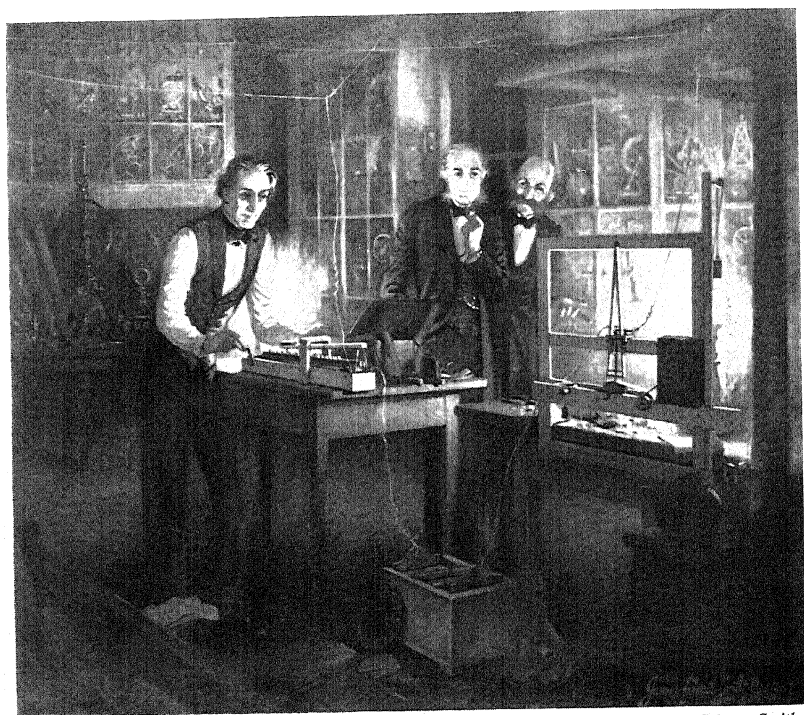
the Connecticut Lyceum, the first separate classroom building which Yale ever had. Later came the northernmost dormitory, the classrooms served as living quarters for impecunious students who were given their rent as recompense for keeping the floor and hearth swept and the desks dusted. Behind Connecticut Hall stood that dismal institution known as the Commons, where food was of such a character that tutors, who ate on elevated platforms, were required to be present to maintain decorum and where the college authorities, apprehensive of costly outbreaks, dispensed with china and glassware in favor of a complete line of pewter dishes. Life was simple in the days of the elder Dwight. Many a New England youth went through Yale in the days of President Dwight with an expenditure of no more than two hundred and fifty dollars a year. Few of them exceeded three hundred dollars. "But," added Professor Silliman in reply to an inquiry, "I am disposed to think that none of the Southern young gentlemen spend less than \$400, and some of them more."

The education was apparently as simple as the manner of life. Freshmen and Sophomores studied arithmetic and even Juniors recited lessons from an antiquated geography. The tutors drilled the students in Latin and in Greek. Benjamin Silliman taught chemistry in the basement of the Connecticut Lyceum. Young Morse studied French with a private tutor outside the curriculum. The most important intellectual experience which Finley Morse enjoyed in his college course seems to have been the result of the lectures of Jeremiah Day. "Mr. Day's lectures are very interesting," he wrote home in the spring of his Junior year. "They are upon Electricity. He has given us some very fine experiments. The whole class taking hold of hands formed the circuit of communication and we all received the shock at apparently the same moment."

The inadequacies of the Yale curriculum suggest the intellectual poverty of the United States at the beginning of the nineteenth century. In Europe, scientists and mathematicians, building upon the foundation laid by Galileo and Newton, were pushing exploring expeditions far into an unknown universe. Benjamin Silliman and Jeremiah Day were trying to introduce the findings of European science into a nation which as yet had little intellectual life of its own and which still labored under a provincial attitude of



Samuel Finley Breese Morse (1791-1872), portrait by Daniel Huntington.



Courtesy of the artist, James Calvert Smith.

S. F. B. Morse sending an early telegraphic message from an experimental laboratory in New York University, 1837. From a recent painting.

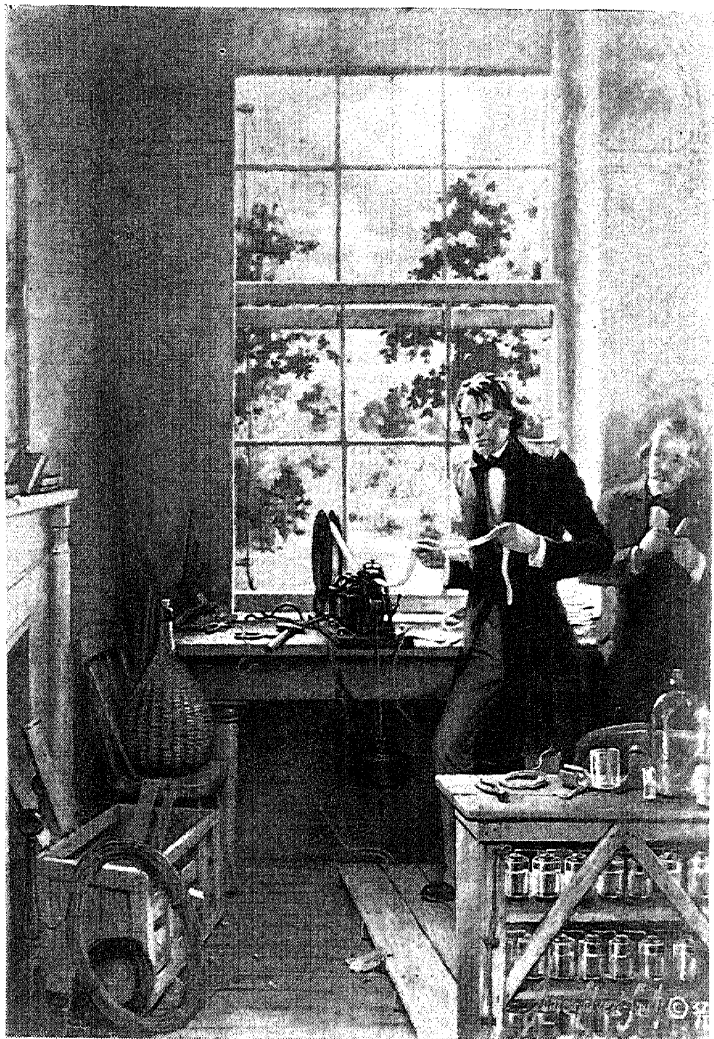
mind. It was not until 1837 that Ralph Waldo Emerson in his Phi Beta Kappa address at Harvard issued that famous challenge to his countrymen to stand on their own feet and to think their own thoughts which is sometimes called the American declaration of intellectual independence. When S. F. B. Morse graduated from Yale in 1810, he was well aware of the shortcomings of his intellectual training. His alma mater had given him virtually nothing to assist him in the work which he most wished to do. Morse had decided to be an artist among people who had few artistic traditions and little interest in or appreciation of art. He had earned spending money in college by painting, for five dollars each, miniatures of his associates. So, as Silliman had gone to Britain to study chemistry, Morse went to London to study painting. He did not become an expatriate as had Benjamin West, who took a kindly interest in him. His work received commendation from competent European critics. After his period of training was ended, he returned to America. He was fired with the ambition to revive in drab, materialistic America, the brilliance of the fifteenth century. Boston elite flocked to his studio to look at the pictures which had won him distinction abroad. But no one offered to buy them or thought of giving him commissions to produce similar canvasses. To his chagrin, Morse discovered that the only things Americans wanted painted were their likenesses. So Morse, dependent upon his brush for his living, became by force of circumstance a portrait painter. He excelled, for he had an eye which penetrated to the character of his subject and the skill to present clearly with lines and colors his estimate of the person.

The United States of the 1820's was not a nation of rich men. Morse became a peripatetic portrait painter who pursued commissions from Concord, New Hampshire, to Charleston, South Carolina. Misfortune befell him. His wife, to whom he was devoted, died in 1825. His father followed in 1826 and his mother left him in 1828. Three of the foundations upon which his life had rested disappeared. Only his art was left. He managed a trip to Europe for three years of further study. In October, 1832, he returned on the packet *Scully*. This leisurely voyage on one of those sturdy, oak-bottomed sailing ships which won America fame upon the seas marked the turning point in his career. He sat at dinner one night with a fellow passenger, Charles Thomas Jackson, who talked

of electricity and displayed one of the recently invented electromagnets which he had acquired in Europe. Since those boyhood days when he had sat in the classes of Jeremiah Day, Morse had been interested in electricity. When commissions were few, he had attended a course of lectures on electricity given at New York City in 1827. But, as he voyaged on the *Scully*, he was an amateur. In 1832 as he talked to Jackson he knew practically nothing of the advances which had been made after 1827 in the laboratories of Europe or in that of Joseph Henry in America. Yet the chance conversation at the dinner table caused a vision, as compelling as that which Jean d'Arc once beheld, to appear to the inner eye of Finley Morse. He saw electricity being used to transmit instantaneously and over great distances the thoughts of men. Like Bushnell's his was a creative imagination.

He spent the remainder of the voyage in work. Before the end of 1832 he had recorded in his notebook the essential features of his invention. These were: a sending apparatus to transmit signals by closing and opening an electric circuit; a receiving apparatus, operated by an electromagnet, to record the signals as dots and spaces on a strip of paper moved by clockwork; and a code for translating the dots and dashes into numbers and letters. He worked for five years while he did a little painting. During these years, with the advice of Professor Joseph Henry, he worked out a system of electromagnetic renewers or relays which would enable him to extend indefinitely the distance through which a message could be transmitted. In September, 1837, he filed his caveat at the Patent Office in Washington.

Then he hurried abroad, where he failed in France and England to obtain patents. Seven years of work and suffering followed. For a time his partner, Alfred Vail, who did so much to perfect the mechanical expression of Morse's ideas, furnished the inventor with money. When the Vail resources failed, Morse sometimes went hungry. He had an old-fashioned Puritan repugnance to running into debt. He visioned the telegraph, which he had perfected and which he demonstrated before President Van Buren, as a government-owned device that would be used for the transmitting of important messages or urgent news. So he asked Congress for an appropriation of thirty thousand dollars with which to build a demonstration line.



Courtesy of the artist, James Calvert Smith.

S. F. B. Morse receiving in the Capitol at Washington the first telegraphic news message in the United States, announcing the nomination of Henry Clay for the presidency by the Whig Party, on May 1, 1844. From a recent painting.

Every American schoolboy is familiar with what followed. In spite of the ridicule of some of its opponents, Morse's bill passed the House. In the Senate it was caught in the legislative jam which was a normal phenomenon at the end of the lame-duck session. On the third of March, 1843, Morse, weary, anxious, and almost penniless, sat in the gallery watching the Senate slowly grinding out its legislative grist. As midnight and the end of the session approached, he saw that the bill upon which his fate hung was so far down the list as to be apparently impossible to reach. He left the capitol rather than witness his defeat.

Not until the following morning did he learn that the measure which meant so much to him had passed. Morse promptly became superintendent of the telegraph line which was to unite Washington and Baltimore. His salary was \$2500. Vail became assistant superintendent at three dollars per day, plus expenses. Vail, taking his cue from British experience, tried to lay the wires in underground conduits but failed because of defective insulation. He then accepted Morse's advice to use poles. Ezra Cornell took the contract to erect these and to string the wires. Later Cornell won a fortune from the telegraphic industry, part of which he devoted to the founding of the university that bears his name. Cornell belted the last insulator at Mount Clare in Baltimore on May 23, 1844. A Grove battery of one hundred cups was provided. On the next day Morse, sitting in a room in the national capitol, sent to Vail the famous greeting: "What hath God wrought." The modern age in the communication of intelligence had begun.

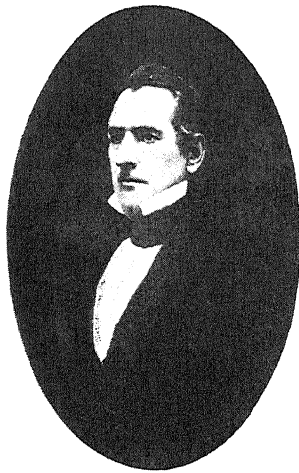
This is not the place, nor is your lecturer competent, to enter upon the long and heated controversy concerning credit and priority, which followed the Morse success. In America, Morse's general idea seems to have been anticipated by his adviser, the scientist Joseph Henry. In England, Wheatstone and Edward Davy had patented ideas similar in many respects to those of Morse. But Morse seems not to have been aware of the telegraphic work of any of these men when he filed his first papers in 1837. His achievement in 1844 was to produce a practicable device. No summary of his work is better than that of Professor Charles F. Scott. Morse was a "teacher of art with an electrical hobby," says Scott. His fate was to "pioneer in a new field, without Ohm's Law, with cut-and-try electromagnets, without measur-

ing instruments, developing complicated mechanisms, with imagination and patience and persistence, overcoming obstacles a plenty—technical and mechanical, financial, political, through a decade to demonstrated public operation, and then a quarter of a century later writing an answer to prove that he really did something.”

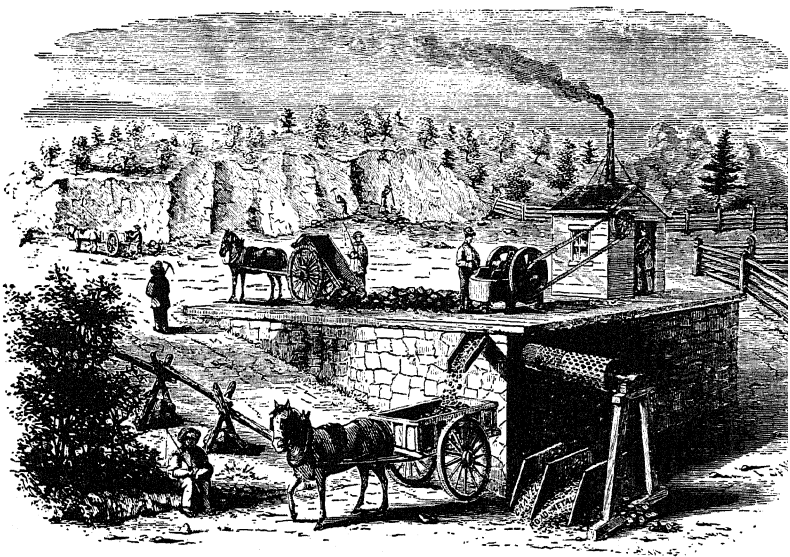
ELI WHITNEY BLAKE

In 1844, when Morse's great triumph came, Jeremiah Day had been president of Yale for twenty-seven years. The venerable successor of the elder Dwight was proud of his student who had won distinction in fields so diverse as invention and art. Wise as he was, President Day probably saw no particular significance, however, in an announcement, which he read in his local paper in 1851, that Eli Whitney Blake had been appointed by the town of New Haven as member of a committee to construct about two miles of macadam highway leading out Whalley Avenue to the small but promising village of Westville. The old president remembered Blake as a student who had graduated in the class of 1816 while Day was still a professor of mathematics and natural philosophy. Later he had known Blake as the efficient assistant of his uncle, Eli Whitney, in the latter's gun factory. Blake's success in that enterprise made him a candidate for the job of building a macadam highway. The fact that New Haven even thought of building such an improved roadway in the middle of the nineteenth century suggests that it was an enterprising city and well in the van of progress in that day. For in all the United States in 1851 there was probably less than a score of miles of macadam road. The reason for this lack of hard-surfaced road is not difficult to discover. Americans had neither the time nor the inclination to go out with hammers and crack rocks necessary for the roadbeds. The roads of America were streaks of dust in summer and of mud in spring. One wonders whether the New Haven carriage makers had anything to do with the suggestion that their city pioneer in the matter of highways. Whether or not they did, Blake, the gun-maker, turned his attention for seven years to road building.

Like Morse, Blake was an inventor but, unlike the father of the telegraph, he had had long training in the use and development of machines. Blessed with that mechanical turn of mind which now for more than half a century had made New England famous, he



*Eli Whitney Blake
(1793-1886).*



Courtesy Arnold G. Dana.

A Blake Stone-breaker about 1870.

set to work to devise a machine which at the rock pile would take the place of the hammer and the human back. Blake faced a difficult task. The trap rock of the Connecticut hills is sturdy stuff. It has the enduring toughness of original sin. Perhaps it is no accident that it was first conquered in the principal stronghold of New England Puritanism. Blake was not content until he had fashioned two mighty steel jaws capable of smashing against the chunks of rock between them with a force of twenty-seven thousand pounds to the square inch. At the end of seven years of thought, study, and experimentation he took out a patent for his stone-breaker. That patent has long since expired. The machine which he designed is now produced by many manufacturers under many names. Improvements in it have been made. In its essential principles the Blake stone-breaker of 1851 is operating in 1938.

The invention is as basic as McCormick's reaper or as Morse's telegraph. Without it the United States could not have been covered with its wonderful network of highways and of railroads. Without it the great dams of the twentieth century could not have been built. Without it reinforced concrete would be impossible as a building material. The muse of history sometimes plays favorites. Before he died Morse stood before a bronze statue of himself erected in the city of New York. During his lifetime McCormick's name was known from one end of America to the other. There is probably not a textbook in American history that does not celebrate the inventions of these two men and with them that of Eli Whitney, creator of the cotton gin. But Blake, whose intellectual achievement was as great as any of the three and whose contribution was of the same basic character as theirs, has been almost forgotten. The ways of history are sometimes as strange as the ways of men.

One's thought runs back to that primitive Yale of the elder Dwight. In the bare classrooms of Silliman, of Day, of Kingsley, and of Dwight the minds of Blake and of Morse were disciplined. With these two undergraduates lived others in the opening decades of the nineteenth century who also were to assist in the laying of those material and intellectual foundations upon which the civilization of twentieth century America rests. John C. Calhoun came from the South and James Fenimore Cooper, whose

college career was terminated abruptly by the authorities, came from the shores of Otsego Lake. In spite of its inadequacies and its poverty the college at New Haven was a significant center of cultural life in a developing civilization.

EARLY YALE ENGINEERS

RICHARD SHELTON KIRBY

ASSOCIATE PROFESSOR OF ENGINEERING DRAWING, YALE UNIVERSITY

IN this fourth lecture in the series on *Inventors and Engineers of Old New Haven* I shall attempt to bring to life a number of Yale engineers of the early 19th century, a period when the College was still emphasizing the classical studies to the almost absolute exclusion of everything else. This, they had from the first believed, was the only way to train men for service in church and civil state. Yale graduates of these decades could presumably parse a sentence from Homer. And they could distinguish between regular, irregular and compound syllogisms. But the few who wished engineering training had perforce to pick it up elsewhere after graduation, either in the hard school of experience, or in one of the two or three less conservative colleges whose faculties already included a professor of engineering.

Specifically then, after some brief and irrelevant introductory remarks on Brockett, New Haven's earliest surveyor, I intend to speak of Mansfield, a nationally famous surveyor, then to introduce two Yale civil engineers, Douglass and Twining, followed by Farnam, the canal and railroad builder, and concluding with a few words about Frederick Law Olmsted.

JOHN BROCKETT

Perhaps it will not be going too far afield if I preface a lecture devoted almost exclusively to Yale engineers by speaking briefly of one who died before the Branford ministers laid down their books to found the little collegiate school, and who was hardly even an engineer.

John Brockett, who probably came across the Atlantic with Eaton and Davenport and the rest, and who at any rate came with them to Quinnipiack in 1638, had somehow learned in London to know what a right angle street corner is and how to manipulate the crude surveying instruments of his day. He was still a young man under thirty when he laid out our nine squares, the center of the future

city, so accurately, parcelled off house lots for each of the proprietors, and set it all down on a map, which unfortunately has not been preserved.

Brockett lived in New Haven for more than thirty years, on Church Street just below the Poli Theatre. No one knows what he looked like. That he was one of the principal men of affairs in the community and respected for his integrity and good judgment is obvious as one scans the early records, where his name appears frequently. He knew just how to pacify the neighboring Indians, who were often distressed because the townspeople's cattle and hogs ruined their cornfields and frightened their squaws and papooses. He served as inspector of highways, and was once asked to consider a wild proposal to divert the Beaver Pond Spring into the city to run a mill or two. If New Haven had a city engineer at that time, obviously Brockett was it.

Gradually Brockett's survey duties carried him farther and farther from the center, first to lay out the Neck, or Fair Haven, then down toward Milford and out to the north and east. In this connection I cannot resist quoting from the records of the New Haven town court for 1658, only a short twenty years after the first settlers arrived. It seems that Brockett had been called down to Malbon's Cove—wherever that was—to determine the disputed boundary between two tracts. We read:

"The Magistrate then spake to Thomas Mullener not to hinder the surveyer in his worke when he came, but let him goe on quietly, and if his field that is fenced in falls out of ye line, it should be considered after; yet notwithstanding he hindered them, and when they set downe their sticks he pulled them up and threw them away and would not suffer them to go on, saying unless they bound him hand and foote and caryed him to prison, he would hinder. Wherefore it is now propounded to the Court, what they judge of his cariage [behavior] and how they would Order the line betwixt Mr. Goodyeare and Thomas Mullener to run."

Evidently even in Brockett's day a surveyor's life was not precisely a bed of roses.

In 1667 he was commissioned by the Governor of New Jersey to lay out Elizabeth Town (now Elizabeth), the first English settlement in that state. He lived down there for two or three years, apparently intending to remain, but Jersey mosquitoes or the Jersey brand of Presbyterian theology drove him back to Connecticut.

With some hundred other New Haveners, Brockett left New Haven in 1669 to found Wallingford, whose streets and town lots he may have marked out. He represented that town for years in the General Assembly, lived to the ripe old age of eighty and had ten children. One of them, named "Be Fruitful", died while still in long clothes. Another, a girl, was named "Silence"; we hope this was no ironical reflection on Mistress Brockett's conversational powers.

JARED MANSFIELD

We must now pass over a period of nearly a century. The Collegiate School, founded about twenty years after Brockett's death, had moved to New Haven in 1716, and, now known as Yale, had grown to a college of nearly two hundred students. The placid little town had, in the meantime, increased to a population of perhaps three thousand. And civil engineering was just beginning to be vaguely thought of in Europe as a distinct profession.

As a prelude to our discussion of a group of Yale and New Haven engineers I want to introduce Jared Mansfield, the only New Havener who attained national fame as a scientific surveyor. Just before the Revolution, his father, Stephen Mansfield, an enterprising sea captain living at the northeast corner of Chapel and State Streets, was engaged in the West India trade, molasses and perhaps other more stimulating products, and apparently prospered. At any rate his widow was able to send her eldest son Jared to Yale College during the troublous Revolutionary War period.

Here the records indicate the young man's brilliance, particularly in mathematical subjects. They also suggest certain unfortunate differences with the faculty in matters of standards of behavior, that impelled the said faculty in his senior year to withhold Jared's diploma. This was two years before the British sacked the town, and according to President Stiles, "captivated" poor old Ex-President Daggett. Some accounts intimate that young Jared suffered a similar fate, but was also released. Let me hasten to add that ten years later either Jared or the faculty suffered a change of heart in the disciplinary matter, for the sheepskin was readily forthcoming in 1787, together with enrollment in his original class and an M.A. thrown in; while forty years later still, in his ripe old age, the College awarded him their highest honor, an LL.D.

But to go back to 1777. For some years Jared wandered about

a bit. For nine or ten years he was rector of Hopkins Grammar School, whose temporary quarters were then, I believe, in his Chapel and State Street home. Shortly after this he produced a number of original works on mathematics and natural philosophy that forthwith placed him in the front rank of American scientists. Indeed one of these papers is regarded as the first important contribution to mathematics made by an American. Apparently he derived little income from the sale of such publications, for the simple reason that they were over the heads of all save a select few in this country.

In 1802 West Point had just been organized, and Mansfield was made a captain of engineers and a member of its first little faculty. His name appears on the earliest West Point diplomas. But far-seeing President Jefferson, recognizing his genius, had other more important plans. The rich government lands in the Middle West, particularly in Ohio and Indiana, were being partitioned off for settlement as fast as the aborigines could be crowded back. Never before in history had a problem like this confronted any government. Sections a mile square and townships six miles square were being marked out, mainly under the energetic leadership of our first surveyor-general, Rufus Putnam (cousin to Israel). Rufus was a remarkable character, but an old-school surveyor, who relied for his base lines on his not too accurate compass rather than on observations on the always dependable sun and stars. To make a long story short, President Jefferson detached Mansfield from West Point in 1803 and sent him out to the Middle West to replace Putnam and establish there the accurate survey system which, with only slight modifications, has prevailed to this day throughout the western country. The city of Mansfield, Ohio, owes its name to this New Haven-born surveyor,

After some years as the second Surveyor-General of the United States Mansfield returned to New Haven. Meantime the War of 1812 broke out. During the war, he checked over the harbor defenses of New Haven and some towns farther east. He then set sail by sloop, with his *Lares* and *Penates*, and, escorted by a naval vessel, down the Sound and up the Hudson to the newly re-organized West Point, where he had been appointed Professor of Natural and Experimental Philosophy. There he served with distinction until his retirement in 1828. Colonel Mansfield died in

New Haven and is buried in the Grove Street Cemetery, beneath a marble slab on which is faintly chiseled the following:

"Jared Mansfield. Early distinguished for intellectual power, industry and self-denial. His attainments in classical learning, in Mathematics, Astronomy and Philosophy were pre-eminent. As a public officer, able and faithful. As a Professor and instructor of youth, loved and venerated, of singular integrity. 'His word was a bond.' In the discharge of his relative duties, conscientious. Few have better deserved the character of a wise and just man."

DAVID BATES DOUGLASS

The year after Jared Mansfield and family sailed from New Haven to West Point, a New Jersey boy, David Bates Douglass, was graduated from Yale College near the head of his class. He came near having engineer blood in his veins, if there is such a thing, for his mother was sister to David Stanhope Bates, shortly to become one of the foremost of the line of homespun Erie Canal engineers. His class took their degrees on the 18th of September 1813. Immediately young Douglass applied for and secured a commission in the Corps of Engineers, and within a few weeks was in command of a company of "bombardiers, sappers and miners," that is, an engineer unit. In this capacity he very soon distinguished himself in active service in the military operations about Lake Erie.

At the close of the war he thoughtfully married a daughter of one of the West Point professors, as a stepping stone to his appointment to the same faculty. He doubtless learned this technique at Yale, where such benevolent nepotism has long been a favorite practice. Douglass remained at West Point, at first as Jared Mansfield's assistant, teaching mathematics, natural philosophy, and finally engineering, for some sixteen years. During this time he was detailed to examine and report on many fortifications and in vacations investigated a number of the ambitious canal projects that preceded our railroads.

Finally, as his reputation grew, he was several times called in by the directors of the Morris Canal in New Jersey to advise on their unique problem. In 1831 he resigned his West Point position and for some years devoted his full time to this canal. As nearly as I can gather from the records, both he and the eminent Professor James Renwick of Columbia were engineers of the canal. Perhaps Douglass was a sort of consultant. A word about the Morris

Canal may be of interest, for it undoubtedly ranked second only to the Erie as an early American engineering achievement and cost, in fact, nearly half as much. The canal extended across the State of New Jersey, by a devious route, from tidewater opposite New York to the Delaware opposite Easton, 101 miles in all. Midway, at Lake Hopatcong, it attained an elevation of over 900 feet. In addition to locks, the canal had a series of twenty-three inclined planes, up which the canal boats, after having been floated into cradles provided with little wheels, were drawn. The power was furnished by mammoth water turbines; that is, some of the water from the upper level, in passing down, turned wheels geared to drums, and around the drums were wound the stout ropes that pulled the boats up. It was a daring enterprise, and for a few years a moderately successful one. Here is an extract from a current newspaper account of a trial trip down one of the Morris Canal planes.

"The machinery was set in motion under the direction of Major Douglass, the enterprising Engineer. The boat, with two hundred persons on board, rose majestically out of the water; in one minute it was upon the summit, which it passed apparently with all the ease that a ship would cross a wave of the sea. As the forward wheels of the car commenced their descent, the boat seemed gently to bow to the spectators and the town below, then glided quickly down the wooden way. In six minutes and thirty seconds it descended from the summit and re-entered the canal, thus passing a plane one thousand and forty feet long, with a descent of seventy feet, and advancing seven hundred and seventy feet, in six and one half minutes."

On the completion of the Morris Canal, about 1833, Major Douglass was retained by the City of New York to examine and report on the practicability of obtaining water from outside the city. He made a careful study of the Croton River and its tributaries, and his report outlined the first Croton Aqueduct, substantially as it was built, with the great High Bridge across the Harlem Valley, the reservoir in what later became Central Park, and a second reservoir, which many of us remember, at 42nd Street and Fifth Avenue, on the block now occupied by the New York Public Library. While Douglass's plans were adopted for the construction of the aqueduct, he himself was obliged, on account of friction in the engineer corps, to sever his connection with the Board before work actually began.

Omitting countless minor projects, Major Douglass's other important commission, and one to which he devoted his energies for a number of years, was the laying out of Green-Wood Cemetery in Brooklyn, for many years justly regarded as the most beautiful in the country. Douglass was for a long time not only its engineer, but the president of its board of Trustees.

After planning Green-Wood Cemetery he was called to the presidency of Kenyon College, then a struggling institution in Ohio, where he remained until 1844, just before his death. Major Douglass has then one unique distinction. I believe to date some three hundred and sixty-seven Yale graduates have become presidents of colleges. Among these, Douglass, so far as I know, was almost the only civil engineer. And he was a *rara avis* among engineers, for he was awarded five honorary degrees, including an LL.D. from Yale.

One other remarkable fact regarding Douglass should be noted. He attained to a very high position in his profession, and was able to project undertakings of the first order, with no professional training whatever, not even a period of apprenticeship under a skilled engineer. All of which reflects not only his innate genius but, to a certain extent at least, his contact with some of the Yale College faculty of his undergraduate days.

ALEXANDER CATLIN TWINING

Three years after Douglass graduated from Yale, a brilliant local boy, Alexander Catlin Twining, son of the treasurer and steward of the college, entered the Freshman class. The elder Timothy Dwight was then serving his last year as president (and, I had almost said, was leading his little grandson Timothy around, just as we all have seen the pair, umbrella and all, on the weather-vane of our newest college over on Temple Street. Except that the grandfather died a dozen years before the grandson was born). There were less than three hundred students in the college, four professors, and a few tutors. Following a strong religious bent, Alexander began, after graduation, to prepare for the ministry at Andover Theological Seminary. Why he suddenly gave up this career and devoted his life to astronomy, mathematics and engineering, no one will perhaps ever know. But Alexander returned to Yale, and, under the influence of Professors Olmsted and Silli-

man, went rather deeply into scientific studies and even taught them here for two or three years. Later he studied engineering for some years at West Point, apparently under some special arrangement, perhaps with the aged Jared Mansfield but more likely with David Bates Douglass. He was not registered as a cadet. His astronomical work there at this time, in particular his study of meteors, deserves especial mention. Evidently even in a military atmosphere he was vastly more interested in celestial than in terrestrial artillery.

But problems involving heavenly bodies were shortly to be temporarily dismissed from his mind, for back here in New Haven many influential people were becoming interested in the possibility of railroads north, east and west from the city, and no local person was competent to make the necessary surveys and to decide on proper locations for the roads. So young Twining returned to his native city to undertake this kind of work and for the next few years concentrated on railroad surveys and reports. The railroads that center at New Haven were all (except the Air Line and the much later Derby road) planned by Twining, who reconnoitered the country through which they were intended to go, mapped and staked out their routes, and made comprehensive reports to their boards of directors in which he defended his recommendations and commented on the physical features of the country and the money-making possibilities of the roads. The first of these was the Hartford and New Haven, on which Twining reported in 1835. This road has practically never been changed from the original location selected by Twining, except that its terminus for ten or twelve years was down at Belle Dock, where its passengers and freight were transferred to the Sound steamers. There was then no other way of getting to New York, except by tedious journeys over the hills by stagecoach, private conveyance, or shank's mare.

The next railroad was the Canal or Northampton Road, of which we shall speak later in connection with one of its builders. This came ten years later than the Hartford and New Haven survey. In the years between, Professor Twining taught mathematics and natural philosophy in little Middlebury College in Vermont. The other railroads that owe their original layouts to Twining are the New Haven and New London, now part of the Shore Line, and the New York and New Haven. He seems not to have been much

concerned in the actual construction of these roads, but rather in the preparatory surveys. He did not confine his activities to Connecticut, for we hear of him farther up the Connecticut Valley and as a consulting railroad engineer in the Middle West, probably for two years at most, during part of this time associated, I believe, with Henry Farnam, of whom I shall speak presently.

Professor Twining did more for his native city than to establish the early New Haven railroad lines. He also mapped out the city's future water supply. His report and estimate, covering a variety of possible sources of water, was made in 1852, and was, for that day, a masterly production. New Haven's twenty-five thousand inhabitants were still slaking their thirst from wells in their respective back yards, and performing their Saturday night ablutions, if any, with cistern water. We shall hear in a subsequent lecture how that soon after this, as a result of Twining's investigations, a forward step was made.

From this time on, that is for some thirty years, Professor Twining, while he did some engineering work for the city on several occasions, seems to have combined the life of an inventor with that of a dreamer. His invention was that of a process for making artificial ice in large quantities. In those days it was no unusual occurrence for natural ice to be shipped in sailing vessels from Maine to Calcutta, India. The idea of producing cold artificially perhaps came to Twining from Professor Silliman earlier in his career. In this field he was certainly a pioneer, one of the first to experiment with the now well-known compression process. Professor Twining filed a caveat in Washington in 1849, and was granted a United States patent in 1853, three years after he had secured one in England. He did much of his experimental work in Cleveland, Ohio. It is recorded that one ice machine of his produced ice at the rate of 1600 pounds in twenty-four hours. While his American patent was twice extended, he seems never to have been able to attract capital sufficient to exploit it properly, and his latter years were years of frustrated ambition.

One United States patent on refrigeration apparatus had slightly preceded Twining's. This was that of the southern doctor, John Gorrie, whose statue the state of Florida placed in the Capitol at Washington many years later. Neither of these pioneers realized his dreams,—in large part, I suspect, because of the lack of

cheap power. Dr. Gorry's failure caused his death. Alexander Twining lived to pursue the same *ignis fatuus* for many years. He was awarded a Yale LL.D. in 1865.

Professor Twining's character shines through his face. Engineering was only one of several subjects on which he was an authority. He was the only engineer, until very recently, to serve as a deacon of Center Church, of which his classmate, Leonard Bacon, was pastor. This high office he held for nearly thirty years, of course until his death.

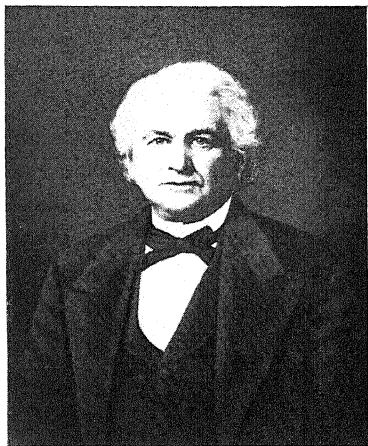
It seems not unreasonable to assume that Alexander Catlin Twining, the railroad engineer, may have influenced the choice of career of his sister's brilliant son, Arthur Twining Hadley. For otherwise Yale's future president might well have duplicated the career of his father Professor James Hadley, distinguished as a Greek scholar, rather than to have become a nationally known authority on railroad economics.

HENRY FARNAM

One engineer on our list had in his youth no Yale connection whatever. Yet neither Yale nor New Haven would think of omitting his name from the list of her favorite sons. I refer to Henry Farnam, father of the late Henry W. Farnam whom most of us knew.

Of Connecticut ancestry, he was born in 1803 on a farm in the Finger Lake district of Central New York. As a boy, farm chores irked Henry, for while his physical energy was abundant, his tastes were mathematical and scholarly. He made such good use of the little education that the neighborhood afforded that he taught district school for several winters while still in his teens. By night he unconsciously absorbed Yale scholarship, devouring a Yale textbook, President Day's algebra, as eagerly and as readily, for example, as a modern youth would a mystery story entitled say, "Murder by Day," or "The Elusive Mr. X." At eighteen he found a place with a construction party on the western section of the Erie Canal, starting in as camp cook but advancing in three months to an assistant engineer position.

As Henry came of age, "DeWitt Clinton's ditch" was finished and, like many another young Erie canal engineer, having graduated from that great practical training school, he turned instinc-



*Alexander Catlin Twining
(1801-1884).*



*Jared Mansfield (1759-1830), from a copy by Robert W. Weir of the
Sully portrait (1828) at the U. S. Military Academy.*

tively to canal work elsewhere. The Farmington or Northampton Canal, which was to extend from New Haven Harbor, passing a few rods north of where we are at this moment, up through Cheshire and Farmington and beyond, was taking shape. Henry Farnam could not resist the offer to return to the country of his ancestors and become an assistant to Davis Hurd, the canal company's chief engineer, at a salary, it is said, of a dollar per day and expenses. Two years later, in 1827, he succeeded Hurd and remained in this position and as superintendent as long as the canal was in operation, that is for twenty years and more. James Hillhouse was, until his death in 1832, the moving spirit in this canal enterprise.

Knowing as we now do how large a proportion of our American canals were doomed to desuetude almost before the echoes of their dedicatory speeches had died away, it is almost pathetic to turn to an appeal made in these early days to timid souls who were all for thinking twice before investing in Northampton canal stock.

"Away then all coldness, all indifference, and all brutal opposition. This canal will shine with meridian splendor when its opposers shall have been for years and ages shrouded in the land of darkness."

During the same year, 1837, just a century ago, Henry Farnam proposed to the New Haven city authorities that the canal company would go out of its way to furnish the town with water. He had two plans to offer, neither of which was accepted. One involved tapping the canal at Love Lock, near the present Winchester factory, and piping the water through Ashmun and York Streets into a reservoir on Broadway, the whole at a cost of only \$23,000. It probably was not planned to drink this water, for sewers had not yet arrived, and each householder still proudly boasted that his well was the best in town. The Twining water-supply report, of which I have already spoken, came fifteen years later than this.

Henry Farnam gave to the canal company the best part of his early life. During this time he was constantly jogging up and down the line with his horse and buggy, called out as he frequently was, day or night, by leaks, washouts, or other emergencies. The company was nearly always in financial straits, and its peripatetic superintendent was more than once obliged to go out and raise funds to tide it over a pay day. Plainly enough the days of canals were numbered, indeed they were already giving place to the more

efficient railroads. And the Farmington (or Northampton) Canal, after only a dozen productive years, had to face serious competition, when Hartford and New Haven became connected by rail only a few short miles to the east.

At this point Joseph Earl Sheffield of Southport and New Haven, a capitalist lately back from the South, of whom we shall hear more in a later lecture, comes into the picture. At one time he owned most of the canal stock, which was far from gilt-edged.

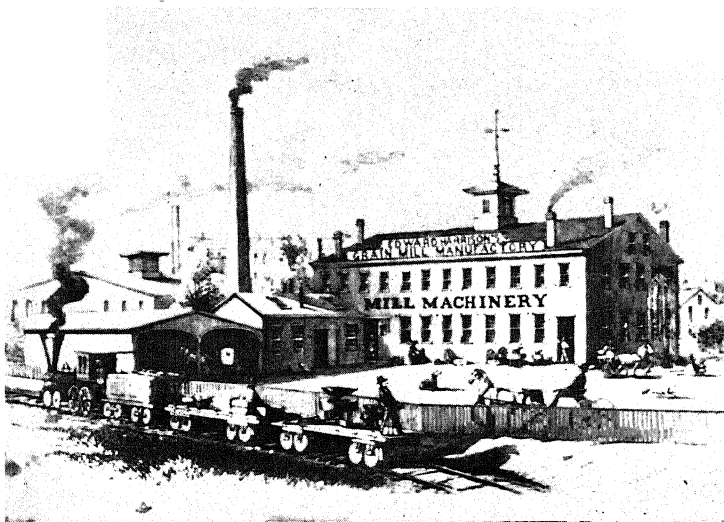
Here we again see Alexander Catlin Twining, called in to look the canal over and advise as to the practicability of building a railroad along its banks, and carrying passengers and freight with the greater speed and regularity that a new generation was demanding. Between these three men, Sheffield, Farnam and Twining, the canal in 1847 became metamorphosed during a single season into a railroad,—we still call it the Canal Road. Henry Farnam continued for several years as chief engineer and superintendent of the railroad. During this time he interested himself for some months in the projected New York and New Haven road which Sheffield was trying to convince Connecticut people was necessary, and was helping to finance. Henry Farnam travelled the entire distance to Greenwich with his horse and buggy, which by this time must have become a little footsore and shopworn, respectively, and secured releases from conservative farmers for the right-of-way over most of the distance. The New York road was at first regarded as a highly visionary scheme, partly because of the rough and rocky country it must traverse and the many rivers it must cross, but more because steamboat connections were already well established and satisfactory to most people. Farnam became one of the original incorporators of the road, but left this part of the country for more promising fields just as it was being completed.

The two decades preceding 1850 had been marked by feverish activity in railroad construction throughout the eastern United States. The result was that most of our principal roads in the Atlantic coast states had been built and the mid-western states were laying down local roads rather indiscriminately and clamoring for rail connections to the more opulent east. Especially was this true of Chicago and St. Louis, which, except for their strategic positions, were then little more important than New Haven was, all three of them cities about the size of present-day New London or Norwalk.



Courtesy of Mrs. Henry W. Farnam.

Henry Farnam (1803-1883), from a daguerreotype of about 1846.



Courtesy of Arnold G. Dana.

Freight train on the Northampton Railroad near Orange Street, about 1855-60, from an engraving by Lockwood Sanford.

The Hudson River Railroad had just been completed. Its widely known chief engineer John B. Jervis, who also had been a canal engineer, transferred his activities to the middle west, as many others of his profession did. For the men of that section, while they did not lack enthusiasm and confidence in the future, were, by and large, not men who could plan, finance, and build railroads.

Joseph Earl Sheffield and Henry Farnam, realizing all this, combined forces, went out there, perhaps at Jervis's instigation, and took hold of a railroad that had been struggling westward across the lower part of the state of Michigan, very haltingly, for some years. Its objective point had now become Chicago, and before many months the new contracting firm, with Sheffield as financier and Farnam, ten years younger, experienced in general construction problems, and tremendously dynamic, in charge of operations, brought it into Chicago just ahead of its nearest competitor, the Michigan Central. The road, of which they completed the last link of 167 miles, was the Michigan Southern, which some years later was combined with the Lake Shore.

The bringing of this road into Chicago was but a prelude to Henry Farnam's most important railroad project, which the pair had in fact already entered upon before the Michigan road was quite complete. This was the construction of the Chicago and Rock Island Railroad, optimistically visualized by its projectors as one link in what eventually was destined to be a trunk line stretching from the east far out across the prairies in the most direct line toward Utah and perhaps even Oregon and the Pacific Coast. Sheffield and Farnam agreed to build and equip this 180-mile road, ready to operate, for about \$4,000,000. The time limit set was somewhat less than four years. In their contract was a provision that, if the railroad should be finished and equipped in less time, the contractors might operate it themselves to their own profit until the date set for completion. Sheffield and Farnam finished the road in half the allotted time, and after operating it for some five months, turned it over to the company a year and a half ahead of the contract date. The contractors received from the company only a little hard cash in payment for their work; the far larger proportion of their remuneration was in securities at par, a not unusual practice in those days. In agreeing to such an arrangement, they took of course, a rather long chance. Some time during these

months Farnam became president of the road, a position which he held for a decade. Joseph Earl Sheffield, at this time past sixty, gradually withdrew from active interest in railroad building. The completion of the Rock Island road early in 1854 was marked by a celebration almost national in its scope, a railroad festival it was called, "the espousal day of the Mississippi River and the Atlantic Ocean." With warm weather an even greater celebration was staged. Six Mississippi River steamboats took a thousand people, brought by the road from Chicago, for a four-day excursion up the river from Rock Island to St. Paul and back, all as guests of Henry Farnam and the Rock Island Railroad. Included in the party were the ex-President of the United States, Millard Fillmore, several governors, many other national figures, and a large group of substantial New Haven people, some of them doubtless stockholders or at least good prospects. The president of the road restricted the beverages during the trip to coffee, tea and water.* In spite of this unusual prohibition, enthusiasm reached a height which we of this generation are almost inclined, in our sophistication, to ridicule. The *Chicago Tribune* described it as the most magnificent excursion, in every respect, that had ever taken place in America, which was doubtless not hyperbole.

It soon became obvious that the Mississippi could not remain indefinitely a hazard to the march of western migration. The earlier emigrants had been ferried across on flatboats, but the Rock Island road was determined to provide a bridge. Farnam forthwith organized a bridge company, with himself as president, and, waving aside all obstacles, proceeded to plan and build a seven-span wooden bridge, more than 1500 feet long, the first bridge across the Mississippi south of St. Paul, indeed for some years the only bridge. In the bridge was a draw span which, in deference to the river steamboats with their lofty smokestacks, was allowed to remain open except on the rare occasions when a train came along. Or, as a contemporary account ran, "The draw will always be up, save when the cars are actually crossing, which can never occur when a steamboat is passing, except by the grossest

*I have never seen the complete passenger list. There were, I repeat, plenty of governors aboard. I have it, on rather questionable authority, that it was on this festive occasion that the Governor of North Carolina made his classic observation to the Governor of South Carolina.

negligence." Henry Farnam, by the way, had sufficient confidence in his design to operate the first locomotive that crept across his bridge.

Steamboat companies and other St. Louis interests fought this bridge from the time of its inception, by fair methods and foul, for years. Some of them tried to burn it, and almost succeeded. The bridge company had on its legal staff a rising young lawyer of Springfield, Illinois, Abraham Lincoln by name, whose arguments in favor of a railroad's right to bridge even the mighty Mississippi are as convincing as ever. In the course of years the bridge became outmoded and was replaced.

The Rock Island road, under Henry Farnam's presidency, aspired to reach out across Iowa and even beyond. He himself became a director of the Union Pacific, which completed the transcontinental connection soon after the Civil War. Meanwhile he withdrew from active affairs, and spent the remaining twenty years of his life in travel and in comparative quiet at the home which he had built on Hillhouse Avenue here, the house which only lately has been remodelled into a residence for President Seymour.

This is not the place to recount Henry Farnam's generosity to City and University. President Porter used to insist that his public spirit was a passion. His Yale connections increased with the years, and have even expanded posthumously. The first modern dormitory on the old Yale Campus, Farnam Hall, was his gift to the college, in fact merely the concrete evidence of one of his many gifts. He made possible, in 1883, just before his death, the Farnam Drive, an engineering achievement by which the summit of East Rock is reached from Orange Street, starting up the westerly slope.

FREDERICK LAW OLMSTED

The other day I ran across the original report on East Rock Park, made in 1882 by the versatile Donald G. Mitchell (Yale 1841), author and amateur landscape architect, whose former residence still adorns Forest Road in Westville. It is in large part to his talent that we owe the plan along which this park has been developed. Mitchell's interesting original map is included in his report. In this report incidentally is a notation that Yale College donated twenty acres of land for the park; this is the tract near Cold Spring Street, now used in part as a playground.

Speaking of park development leads us naturally a very little away from our main topic, Yale engineers, to close with a brief sketch of perhaps the most outstanding landscape architect this country has yet produced, Frederick Law Olmsted. This man's active career, begun before the Civil War, extended over a period of forty years; in fact his influence is still widely felt.

Our official alumni records do not show that Olmsted studied here at all. As a matter of fact in the strictest sense he did not. But, in his case, eager attendance on Professor Silliman's inspiring lectures during two winters in the 1840's provided all the college training that a young man of his temperament and abilities required. Hailing originally from Hartford, Frederick spent parts of two years as a youth in the general neighborhood of New Haven, some of it at lovely Brooksvale in Cheshire, while his younger brother was a Yale student. Apparently an attack of sumac poisoning was the only thing that prevented his entering Yale. His brother's class, 1847, later made him what they were pleased to call an honorary member.

His first attempt at landscaping was made on a small farm plot that his indulgent father gave him down at Sachem's Head, and later on a larger farm on Staten Island. At this period scientific agriculture interested him most. But it was only a step from this to the landscape architecture that occupied his attention for the rest of his long life.

It is difficult for us to realize that, before the Civil War, practically no American cities had thought it necessary to provide, on their outskirts, large tracts of land over which the public might roam at will, whenever they felt the urge to escape from the city's din and confusion. A park meant, to an American of those days, something much smaller, like Battery Park and City Hall Park in New York, or even the New Haven Green or the Boston Common.

But in the 1850's the new idea was beginning to take root in several American cities, largely under the leadership of men who had the vision of reproducing here for public enjoyment something comparable to the vast private parks of the mother country. New York men like William Cullen Bryant, Washington Irving and Peter Cooper were urging the intelligent development of a rough barren tract toward the north of Manhattan Island, called Central Park.

Young Olmsted was made superintendent of this embryo park, and shortly thereafter the elaborate development plan made by him in collaboration with his architect friend Calvert Vaux was accepted. Here Olmsted had opportunity, as official landscape architect over a period of years, not only to exercise his talent for planning beautiful landscape effects, but periodically to fight political corruption in high places, for Tammany Hall was then uncommonly aggressive and did not yield gracefully to the will of men like Olmsted. In the years that followed, Olmsted, more than any other single individual, convinced the American public, with voice and pen, that parks were, from every angle, a profitable municipal investment.

Merely to catalogue the other park developments in which Frederick Law Olmsted was the leading spirit would be a tedious undertaking. If one should mention, however, a few, they would be the University of California grounds and the village of Berkeley, Riverside Park in New York, Prospect Park in Brooklyn, Leland Stanford University grounds, Bushnell Park in Hartford, Vanderbilt's Biltmore Estate in North Carolina and the epoch-making Chicago World's Fair grounds of 1893. Our original Yale Field was of his planning.

Olmsted rode and tramped through the South just before the Civil War. His record of conditions as he found them there constitutes what has been called the most sympathetic, accurate and unbiased account of the situation written by a northerner. If more of his type had followed Olmsted's example, perhaps we might have been spared the horrors of our Civil War.

When he was past 70, in 1893, both Yale and Harvard, with a unanimity of opinion that has been rare, honored Frederick Law Olmsted with LL.D. degrees, I suppose on two successive days.

Most of the Yale engineers after Olmsted's day were systematically trained for their profession in the school which Joseph Earl Sheffield's generosity made possible.

Before I close I cannot resist injecting a few words of postscript on the brilliant achievement of the younger Professor Benjamin Silliman that narrowly escaped being an indirect contribution to engineering. In this machine age we should be considerably handi-

capped if we were suddenly deprived of all petroleum products. Petroleum was, however, up to less than eighty years ago, a natural curiosity, but not much more. In 1858 or 1859 Edwin L. Drake, a railroad conductor of New Haven, was sent out by the Pennsylvania Rock Oil Company, a New Haven concern, to Venango County, Pennsylvania, where crude oil was bubbling up in springs. There he drilled for them the world's first oil well. Several years earlier, in 1855, some of the curious product had been sent back to New Haven, where Silliman, after determining its composition, had ingeniously separated it in his laboratory, by successive distillation, into four components, whose characteristic properties and probable usefulness he described in a report to the company. This report, after being meticulously copyrighted, was laid away for years, for the company lacked intuition or something and preferred to market the petroleum mainly as Seneca Oil, a cure for an imposing list of human ills, from toothache down through cholera morbus to corns. Meanwhile, some years later, the canny John D. Rockefeller and others found chemists who, using Silliman's methods, produced what we now call kerosene, the various grades of lubricating oils, and paraffin, and years later, when the demand finally arose, gasoline.

THE FORMATIVE YEARS OF NEW HAVEN'S PUBLIC UTILITIES

HENRY HOTCHKISS TOWNSEND

BY 1847 New Haven had reached that point in the growth of civic consciousness and in population (about 22,000) that called for the introduction of some of the new contrivances that were making our cities more convenient places to live in. Oil lamps, candles, wells, cisterns, shank's mare, the Post Office and the Tontine Hotel, where men met and exchanged the news of the day, had supplied the needs of the community in respect to those necessities of communal life that many years afterwards were to be grouped together under the technical term Public Utilities. When this term first came into popular use, I do not know. It certainly was not common in my boyhood days. Its general acceptance and now well-known connotation is a matter of quite recent development.

GAS LIGHTING

I have heard the family speak of the days of oil lamps. Spermin oil at about \$2.50 a gallon, a combination of turpentine and alcohol which probably was cheaper, and tallow candles, furnished the principal sources of illumination. The ability to continue human activities after darkness had set in, important as it always had been, was becoming a greater need in the business and social world. Professor Benjamin Silliman, Jr., keenly alive as he always was to everything new, became actively interested in lighting by gas as a vast improvement over the methods New Haven then used. By the latter part of the 1840's, although gas was not new even in this country, few towns as small as New Haven then was had dared undertake the venture. To his creative mind and energetic spirit must be given the credit for its introduction here. When later, in 1855, my family had him analyze and report on the rock oil from Venango County, Pennsylvania, in which they had become interested, he told them that he could make it give a perfect flame with the Argand burner, but he added "These experiments were not prose-

cuted, because it was assumed that other products now known and in use for gas making might be employed at less expense for this purpose than your oil. Nevertheless this branch of inquiry may be worthy of further attention." In May 1847, he, Henry Peck, Atwater Treat, Philip S. Galpin and Lucius G. Peck, all well known and progressive New Haven citizens, had obtained a charter to manufacture and sell gas to be made from rosin, coal, oil, and any other material or materials; and they laid before their fellow townsmen attractive prospectuses of the financial rewards that would come to those who would join them in their \$100,000 corporation. This sum was to be the entire cost of the works and four miles of mains, making full allowance for future growth. The plant would manufacture 40,000 cubic feet of gas a day from bituminous or coking coal and a small portion of resin. Capacity could be doubled with moderate additional capital. This sum of \$100,000 was the agreed contract price between the gas company and Battin Dungan & Co. who had already built and equipped the gas plants at Newark, N. J.

The gas company bought the land on St. John Street, where one of the later buildings still stands, and paid for a complete set of buildings and apparatus to make and furnish carburetted hydrogen gas from bituminous coal. There was to be a stone retort house on a well-secured foundation, with iron rafters, slate tiling, ventilator in roof, and a proper chimney; a counting house; room for a large station meter; work house; lime house and coal shed, well fenced in; a gasometer and tank of 50 feet diameter, of 50,000 cubic feet capacity per day; enough retorts for five benches; hydraulic main; washers; condensers; tar pipes; tar well and pumps; purifying pipes and boxes; drips, connecting pipes and apparatus; besides the station meter, as many other meters as might be necessary, with service pipes (20 feet to a customer); four miles of main pipes. If all went well, 100 cast iron lamp posts were to be furnished. All patented improvements that Battin Dungan & Co. owned were to be used. On this investment at a cost to the customer of \$4.00 per 1,000 cubic feet and an estimated consumption of 15,000 cubic feet per day, a profit of \$12,500 was conservatively estimated, or 12 per cent. Here was the prudent investment theory. The largest item of expenditure was the coal, 270 short tons, \$4,000, and four hands in the retort house at \$1,600 a year.

The superintendent was to get \$600 a year, the secretary \$350, and other assistants \$450. So attractive was this new enterprise that all but 800 of the 4,000 shares had been subscribed for ten days after the books were opened. These 800 the promoters wanted distributed in one- or two-share lots.

On the basis of comparable illumination power, the gas would cost the customer only one-third as much as oil, or one-tenth as much as sperm candles.

This price (\$4.00 per 1,000 cubic feet) was the same as that paid in Albany, Boston, Paterson, Newark and Philadelphia, while New York paid \$7.00 per thousand for a very inferior article. In 1855 the price in New York had come down to \$3.50 per thousand; whether or not the quality had improved, I do not know. In New Haven the price was reduced to \$3.50 in 1860.

Merchants were presumably the first to use this new illumination, as it reduced their insurance by 25 per cent. Then came public halls, lecture and society rooms; and it was hoped that after the ordinary householder overcame his fear of the new contraption, it would go into private homes. The new railroad station was looked upon as a substantial user, and it was anticipated that churches and public houses would follow. The merchants seemed the most likely consumers, and we find the four miles of mains running up St. John Street to State, to Chapel, and on Temple, George, Crown and College Streets. This took in the entire business section of New Haven as it then was. The plant was constructed during 1848 and began to operate toward the end of the year. Durrier & Peck's book store on Chapel Street was the first store to put the gas in. Henry Peck was then mayor. The first residence was, as might have been expected, that of Professor Silliman on Hillhouse Avenue, only recently demolished. The main must have been run up Temple Street for his special benefit. It was a long distance from the chief consumers on Chapel Street, and from what I know of those who lived on Temple Street from the Green north, few would have had the initiative to put in this innovation. It was a great event when Professor Silliman's mansion was first illuminated on Thanksgiving Eve, 1848. In 1849 the first street lights were installed. Actually the first one was at the St. John and Hamilton Street corner on December 2, 1848. They numbered 55 by January 1, 1850, and 189 by 1855. Certain merchants of enter-

prising turn had lights put in front of their stores for advertising purposes, from which the public greatly benefited. Philip Sanders, who ran a grocery store at the corner of Chapel and Orange Streets, was the first of these. By 1856 the number of gas consumers had reached 1,252, and as late as 1887 it was seriously doubted whether the newly introduced electric lights could ever take the place of gas for interior lighting.

No one is now alive who can tell of the difficulties, mechanical and social, that had to be overcome. Many arguments were used against the novelty. Lighting of streets would increase crime; people would be induced to stay out all night; it was flying in the face of Providence, for God had divided the twenty-four hours into light and darkness; it would rob festive occasions of all their charm because it would destroy their novelty. Such were the arguments raised against the use of gas, and knowing my New Haven as I do, I am willing to wager that one or all of these were on occasion advanced vociferously in public and in private.

The consumption of gas was not very rapid during the first ten years. But the estimate in the prospectus was achieved the first year, as 3,180,320 cubic feet were sold to 358 customers. In 1850 it was 5,000,000 cubic feet. After that the customers increased by twenty-five the next year (1850), and dividends of six per cent were commenced in January 1850 and continued at gradually increased rates, with a stock dividend in July 1850. The customers were increased by 114 in 1851, and from then on by an average of about 130 annually until 1860, when the growth became much quicker. But it was not until after the Civil War that the average householder substituted gas for oil. Today there are, roughly, 62,000 customers, consuming 2,374,198,000 cubic feet each year.

One New Haven boy of that time has left his impression of the first gas he saw lighted. It was during the celebration over the Whig election of Zachary Taylor as president. A new lamp post had just been set, without any burner, and the Honorable W. W. Boardman, president of the company, ordered it lighted; whereupon a flame four or five feet high shot up, to the amazement and excitement of young E. C. Beecher.

We ought not to end this short account of the introduction of gas without referring to the boys who lit and extinguished the lamps. They were an institution in themselves. Under the genial guid-

ance of S. Wilbur Scranton, twenty of them, with a waiting list, formed quite a guild, in which there developed a sense of responsibility and regularity in habits that stood them in good stead later in life. After trying a torch and a mechanical contrivance with paper percussion caps, they, in true boy fashion, arrived at the simple expedient of striking a match on the side of the post, sticking it in a split bamboo fishing-pole, opening the cock with the end of the pole, and lighting the jet. This was after they had been forbidden to shin up the lamp-posts. If the weather was rainy or windy, the boys had a little difficulty, but they got so dexterous that it took only six or seven seconds under ordinary circumstances to light a lamp. Their districts were so arranged that they could cover them before and after school in about an hour's time. Several ingenious attempts were made to control the lighting from some central point, but none succeeded in ousting the boys.

WATER SUPPLY

At the same time the city's civic consciousness began to stir in regard to gas, came the throes of providing for a public supply of water. Here, however, was a different proposition. No one thought of the introduction of gas as other than a private enterprise. It had at first only the appeal of luxury. Its convenience was doubted; its economy was questioned. If any wished to indulge in it, they could, but the enterprise was not of such a character that the interest of the city should be invoked to back it. Well lighted highways were not considered a necessity, and from what has been said, might even be considered objectionable. People went to bed early in those days, and certainly no good citizen expected to use the streets much after dark; if he did it was at his own risk. So no one suggested that the city should go into the lighting business.

Water, however, was another matter. There was no luxury about it, for conflagration was an ever-present menace, a serious threat against everyone in the community. The Farmington canal provided protection along the business section of State or Fleet Street and for a considerable distance each side, and numerous cisterns and reservoirs scattered throughout the city, whose location can be readily ascertained by reference to the city directories of the period and which are every now and then uncovered today in street excavations, added to this main supply. But when the Canal

became a railroad, as it did about 1847, and the business section became more and more congested, this question of adequate fire protection became a matter of concern to the leading citizens. The growing demands of the increasing factories and commercial concerns also were making the problem a more acute and pressing one.

To the average householder, a public water supply did not seem much of an advantage. Water for his purposes was easily obtainable. He had only to dig a well of about 20 feet, and sometimes less, anywhere in the then settled part of New Haven, and once dug, it would last forever. In almost all the older houses remains of these wells were evident in my day. In our house on the corner of Church and Wall Streets the well, with water in it, existed down to the 1920's when the house was torn down, and many can remember the town pump that stood just within the Green at the corner of Church and Chapel Streets. There developed therefore two parties, one for a city-owned water supply and one for a privately owned company like the gas company. The latter party was composed chiefly of small householders who, unappreciative of how a general conflagration might affect them business-wise, saw no use in spending money through taxation for a project that would be of no specific benefit to them. Their New England thrift objected to paying for something Nature had put at their very back door, whether it was a general public benefit or not. And there were those who felt that the works could be built and operated more reasonably by a private concern. So when Henry Peck, the same Henry Peck who was interested in the gas company, Ezra Read, Wooster Hotchkiss, James Brewster, and my grandfather, Henry Hotchkiss, obtained a charter in 1849 for bringing water into New Haven and distributing it through pipes, the question of public or private ownership was brought to a head. For the next ten or twelve years it was a burning question constantly before the public.

I know it was my grandfather's firm conviction that it should be a public undertaking. Read and Peck, as members of a commission later appointed by the city, certainly agreed with him and urged this course over their signatures. Why this view was not accepted is a very interesting story.

The incorporators took no steps toward making the company an active concern because, as I have always understood, the charter was obtained to be given over to the city if it would accept it and

undertake the project. Not until June 1, 1852 was anything done, and then at an adjourned city meeting the following committee was appointed to investigate and report: A. N. Skinner, then mayor, Henry White, Ezra C. Read, Charles A. Ingersoll, Matthew G. Elliott, Henry Hotchkiss, William H. Ellis, Henry Peck, and Elias Gilbert. James Brewster and Wooster Hotchkiss were the only incorporators not members of this committee.

This committee employed the most distinguished New Haven engineer of that time, Alexander Catlin Twining, uncle of Arthur Twining Hadley. Twining, with the assistance of Michael Ritner, made a thorough survey of all available sources and a comprehensive estimate of the costs from each source. Professor John A. Porter made analyses of the supply from each source and the effect of each upon lead pipes. This again shows the intimate relationship between Yale and the city, Professor Silliman the moving spirit in the gas company, Professor Porter doing his part in the water question. The report was finished and printed in pamphlet form the next year. It was widely distributed among the Freemen, as they were called, and a city meeting was called to hear and act on it March 26, 1853. The report contained seventy-two pages, fourteen of which were devoted to a most earnest, persuasive and convincing argument for the city to undertake the project, and the unanimous recommendation of the committee that this course be pursued. Twining investigated eight sources of supply—Beaver Ponds, the West River with a distributing reservoir on Beaver Hills; Mill River from Augurville; Mill River from where the Davis Street bridge now crosses; Mill River from the present dam site; (from these sources it was to be pumped to a distributing reservoir on the ridge along which Prospect Street now runs); Quinnipiac River from North Haven to a distributing station on East Rock; Quinnipiac, Pine River and Horton Brook to a reservoir on the northeast slope of East Rock; Pine or Muddy River direct to the city.

Of all these sources Pine or Muddy River was the only one from which the supply could be brought into the city by gravity. In all the others pumping by steam or water power must be used. A gravity supply was the most desirable, but the long distance, some thirteen miles or more, and the expense and difficulty of bringing it over or under the Quinnipiac River valley, made this project

not feasible. In the final analysis only three sources were deemed worthy of consideration: (1) Mill River from where Davis Street now crosses, by open canal to the site of the present dam where the natural fall would pump the water to the reservoir on Prospect Street and by a 20-inch main to Temple and Elm Streets, cost \$190,000; (2) Quinnipiac, Pine River and Horton Brook by open canal to north side of East Rock by pumping it to a reservoir there and thence to Elm and Temple Streets, cost \$213,000; (3) from the same sources by open canal to Cedar Hill by pump to a reservoir on Indian Head and thence by main to Elm and State Streets, \$202,000. About sixty gallons a day per inhabitant would be ample. The committee definitely recommended city ownership, and that pumping should be done by water power. It did not recommend which one of these three schemes should be selected, but did ask that a sum of \$325,000 be voted for whatever project should later be adopted, and to persuade the reluctant, encourage the timid, and abash the opposition, assured the citizens "that after passing the strict necessities of the person and of the household, the quantities in which this element of life and comfort will be used for purposes of salubrity, neatness and luxury, will be increased a hundred fold when it comes self-conveyed to the chamber or the garden, and may be thrown in refreshing and purifying abundance upon the sidewalks, streets, foliage and buildings."

The vote on March 26, 1853, resulted in a majority of 117 in favor of city ownership. A Board of Water Commissioners was organized, and after five months' study consummated a contract with Eli Whitney for the construction of the works, for the purchase of land and for water privileges. This contract was signed January 2, 1854, referred to the Common Council, and published in the papers. In the meantime the legislature had amended the city charter so that it could undertake the project, and authorized the issue of \$325,000 of bonds. All of which was legally accepted by the citizens on July 25, 1853. Unfortunately this act omitted to state who should execute and issue these bonds. Consequently another city meeting had to be held on January 4, 1854, to designate such a person. The opposition saw its chance. For more than six months the controversy between public and private ownership had been fierce, and to the utter surprise of my grandfather and other friends of municipal ownership, it was moved to defer all

action until July, the meeting adjourned for a month, and at this adjourned meeting Henry Peck, one of the commissioners and one of the incorporators, moved that the commission stay all proceedings, that the whole matter be again laid before the Freemen, and that \$325,000 be the entire cost.

Wearied with the persevering and continuous opposition to municipal ownership, a town meeting on June 6, 1854, voted to ask the legislature to repeal the amendment permitting the city to engage in this business. A bill was passed ordering another election requiring a three-fifths favorable vote, and appointing the city treasurer agent to issue the bonds. This town meeting on July 17, 1854, defeated the proposition for municipal ownership by a 608 majority.

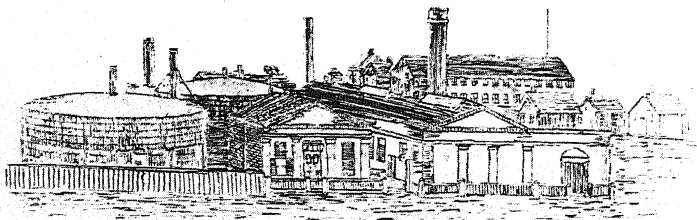
I do not know whether it was at this meeting or an earlier one that, in the heat of debate, a citizen whose name I have fortunately forgotten, asked what need there was for running water—look at him—he had no use for a weekly bath. And ever afterward he was known as “the great unwashed.”

Municipal ownership was now dead. But the original charter was still alive. The first meeting of the incorporators had been held and subscription books had been opened in 1850. Fifty thousand dollars of stock had been subscribed for, and a board of directors—Henry Hotchkiss, William W. Boardman, Lucius Hotchkiss, Ezra C. Read, Henry Peck, L. Cannon, and James E. English—had been elected. Numerous amendments to the charter had been obtained. The fierce opposition and almost continuous agitation wore out the patience of many, so that none of the original incorporators or board of directors was with the company in 1859. On the 14th of July in that year the then board—E. C. Scranton, James F. Babcock, Henry G. Lewis, Henry S. Dawson, Minotte A. Osborn, David Cook, and David J. Peck—made a contract with Eli Whitney and Charles McClallan & Sons to construct the works for \$350,000, \$175,000 in cash, \$75,000 in stock and \$100,000 in bonds. Books were again opened for subscription, but so bitter had been the fight over this matter during the preceding years that it was only after great effort that \$250,000 was secured and the work commenced in the spring of 1860, a very different situation from that of the gas company. Eli Whitney, with whom the former commissioners had to settle for their breach of contract when the town

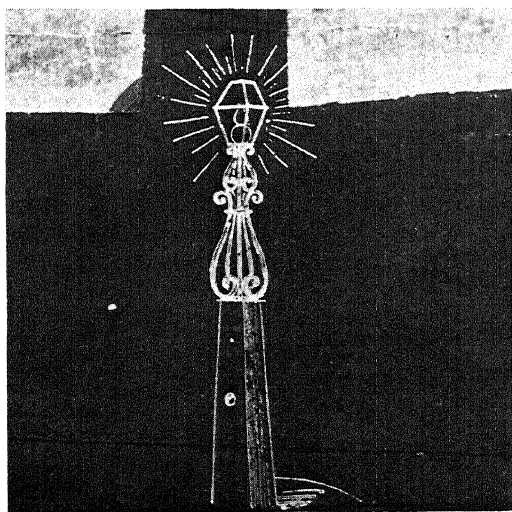
repudiated the earlier agreement, subscribed \$25,000 and the contractor \$75,000, and as the work progressed, Whitney kept it going by payments from his personal resources. Some repudiated their subscriptions absolutely; others, on account of the distressed situation (the Civil War was just coming on) failed to meet their obligations. A rival company, known as the Mountain Water Company, made threatening gestures, and by joining its interest with a third company known as the Fair Haven Water Company, was a constant threat, especially when it came to negotiating with the city as to water rates. Finally, on December 2, 1861, the company commenced to pump water into its reservoir on Prospect Street from Mill River, dammed up as we now know it, and on January 1, 1862, water was introduced into the seventeen odd miles of mains, from the Derby turnpike on the west to the Quinnipiac River on the east. The original nine squares were completely serviced, also the portion of the city from the railroad cut eastward to Mill River and the harbor. The distributing mains were of cast iron of varying sizes. The mains ran out Whitney Avenue to Humphrey, Prospect Street to the railroad, Broadway to Howe, Chapel Street to West Street, Oak Street to Howe, Congress Avenue to Cedar, State Street to Mill River, Orange Street to Pearl. During that year two miles of pipe were laid in Fair Haven, partly to counteract the efforts of the Fair Haven company. Service connections were made during the spring of 1862. Public sentiment began to change, and even "anti-water men" as they were known began to take advantage of this new improvement, so that by January 1, 1863, there were 493 consumers. The final cost was about \$350,000.

Most of the consumers' connections were lead—Professor Porter had declared these were not affected by the water. But one that supplied Ezra Read's home, where the Security Insurance building now stands, was made of hard rubber, a personal precaution on Read's part, I suppose.

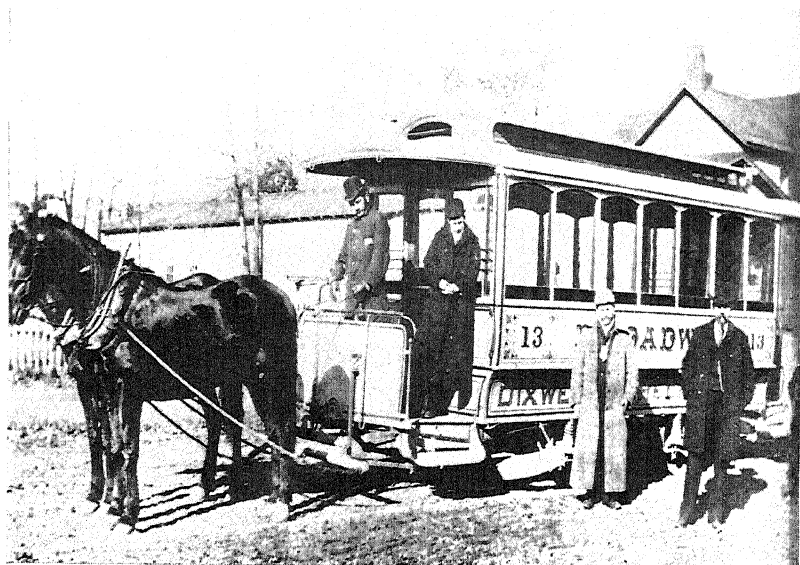
After the usual trials that accompany such negotiations, a contract was entered into with the city for a supply of water for municipal purposes. The contract was certainly not onerous on the city. It contained a provision whereby the city could purchase the plant at any time after ten years for the amount paid in and invested, plus 10 per cent per annum on the same. This contract ran



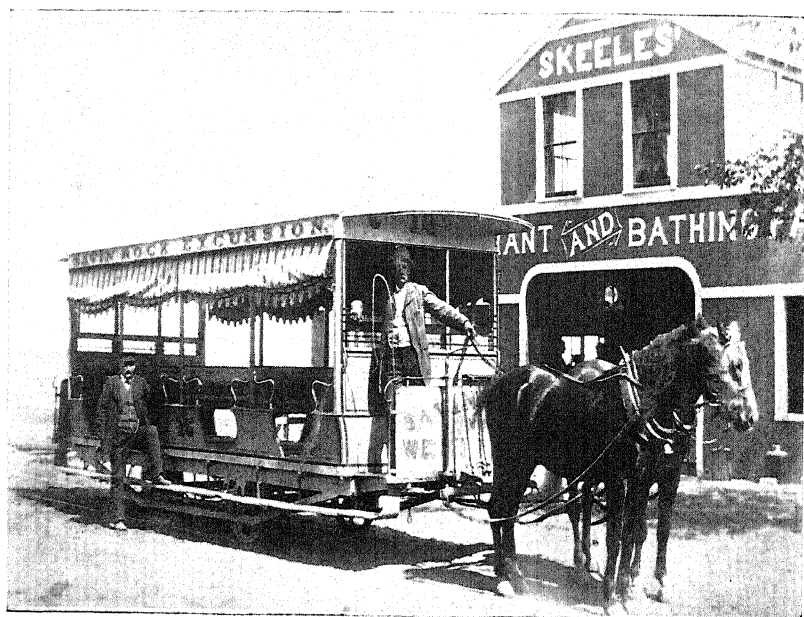
New Haven's original gas works. From an engraving on a silver platter presented to President W. W. Boardman in 1858, now in possession of the New Haven Gas Light Co.



One of New Haven's twenty-five street lamps, 1848.



Courtesy of John B. Judge of the Connecticut Company.



Courtesy of John B. Judge of the Connecticut Company.

Early New Haven Horse-cars.

for twenty years. Since its expiration in 1882 three others have been consummated, in each of which the city has again had the privilege of purchase. Each time these negotiations and renewals arrive, an occasion is provided for the usual display of fireworks, but no earnest desire for municipal ownership has developed.

In 1862 the Gas Company paid \$1.00 for all the water it could use at its works or to test its pipes.

It was not until 1867 that the Water Company felt itself able to reimburse its sponsors with a dividend of 2 per cent. From then on there have been payments of varying amounts, while a regular rate was established in 1879.

The pumping equipment installed at the Whitney dam was very unusual for its time, and represented a high degree of mill work and engineering skill. There were two overshot water wheels 30 feet in diameter, with blades about 6 feet wide. These operated two displacement pumps and were connected with a flange, which enabled either wheel to be operated independently of the other. With both wheels in operation and both pumps supplying water, 3,000 gallons per minute could be pumped up on Prospect Hill, a very noteworthy performance for that day.

From Twining's report, the minimum flow of Mill River in the driest time was $11\frac{2}{3}$ million gallons each twenty-four hours. This seemed to the committee sufficient to "supply the city for any probable population," though extra pumping might be necessary. But not so very long after this ample supply was inaugurated, a fire engine was employed to pump from below the dam into the lake to keep the water level up, and today the claim that the water being taken 20 feet below the surface would be free from all possible contamination seems a bit optimistic.

The Puritan mind again found religious grounds for objecting to paying for this new convenience. One individual told Whitney that the Lord gave the water, and therefore he (Whitney) had no right to charge for it. Whitney called his superintendent and gave a written order to let this person have as much water as wished, free—at the reservoir.

STREET RAILWAYS

In the 1860's Westville, or Hotchkissville as it was formerly called, was almost a separate community. There was a long stretch

of open and sparsely inhabited land between it and New Haven. To the east was Fair Haven proper, that section lying between Mill River and the Quinnipiac. This, too, was far enough away from the business center of New Haven to have an identity of its own. But as these lesser satellites had to revolve around the business center of the city, it meant a rather long and tedious journey back and forth for those not blest with possession of at least a horse and buggy. Here was another opportunity for capital and enterprise, and both were quickly forthcoming, for it was a time when neither was discouraged and men had faith.

To meet this need, a charter was granted in 1860 to Henry Peck, N. D. Sperry, Benjamin Noyes, S. L. Blatchley, James F. Babcock, Edwin Marble, Smith G. Tuttle, Lucius G. Peck, L. R. Finch, William M. White, John B. Carrington, Thomas W. Ensign, George A. Shubert, Seth F. Benton, Alfred C. Sperry, E. B. Munson, and E. S. Rowland to carry, "by force and power of animals," "persons and property," on a railroad of not more than two tracks from the east end of the Grand Avenue Bridge through Grand Avenue to its intersection with Olive, down Olive Street to Chapel, up Chapel to York, to Broadway, through Whalley Avenue to Blake Street, and to a terminus at the Parker Paper Mill. Numerous branch lines were authorized connecting with this main route, none of which was ever built. Branches through Church Street, out Congress Avenue, and through State Street to Chapel, down State Street to Fleet Street, could be built only if, in some cases two-thirds, in others a majority, of the abutting owners wanted it, and no tracks were ever to be laid on Elm Street or on lower Chapel Street from Olive to East. The merchants of State and Church Streets were evidently not convinced that this horse railroad would be a convenience to them, and the residents of Elm and lower Chapel Streets were convinced it would be an annoyance. They were not going to have their nerves upset by the terrible roar of horse-cars passing their doors. The stately mansions of the Trowbridges, the Bristols and the Ingersolls on Elm Street and the more modern homes of the Englishes and my grandfather on Chapel Street must not have their privacy invaded or their peacefulness upset by jangling horse-car bells and the motley crowd that this new contrivance would bring. The section around Wooster Square, or the New Green, as it was then called, was being

built up at that time by those who believed it was the coming residential section. All this sounds strangely familiar to those of us who remember the opposition that nearly always sprang up during the period of trolley expansion.

This company had an authorized capital of \$100,000, which could be increased to \$300,000, and the fare from Fair Haven to any point east of York Street and from Westville to any point west of Olive Street was to be five cents. The same toll was permitted from any point to any other point within the city proper. Letters in my possession from some of the New Haven boys who went off with the Grays in the spring of 1861, after bragging about what they were going to do to the Rebs, say they will be glad to see the horse-cars on Chapel Street when they get home. These were written before Bull Run. They were home by August, and the cars were there. The first one was run from Grand Avenue to Chapel and State Streets on May 4, 1861. This finished the construction at that time. Two cars were run, and a total of 402 passengers were carried on the gala occasion.

The entire issue of 4,000 shares of \$25 par was taken between August 15 and 17, 1860, by eleven of the directors. That their confidence was not misplaced is evident from the fact that a dividend of 40 cents was paid September 2, 1862, and that dividends continued at varying but increased rates thereafter. At no time was there any difficulty in financing this new project, though it came in the midst of the war. An increase of stock in 1863 was practically all taken by February, 1864.

The construction of the road was commenced in the fall of 1860, probably in September. S. R. Dickson was the contractor, and he was paid \$56,050 on June 24, 1861, for his work on the road as it stood at that time,—ten horse-cars, forty horses, twenty sets of harness, and all other articles necessary and proper. Four thousand and sixty dollars was reserved for paving and completing the road in Fair Haven and its completion to Howe Street and Whalley Avenue. The entire cost was not to exceed \$60,000. On the day the first cars were run from Fair Haven to Chapel and State Streets, the directors voted to continue the construction up Chapel Street to York and thence to Broadway near Christ Church, thus completing the program as laid out; this must have been accomplished by the fall of 1861 at any rate, probably in the summer.

The cost of laying the track, not including material, was \$487.50 a mile. Here the matter rested. We were in the midst of the Civil War. The price of everything was rapidly rising. People were engrossed with saving the Union, and on November 11, 1862, it was voted not to extend the line to Westville, on account of the high cost of iron. The road was finally extended through Whalley Avenue to its junction with Fountain Street in 1864. The old witticism that a conductor, accosting a gray-bearded passenger in Fair Haven, failed to recognize him as the dapper young man who got on in Westville, does indicate the length of the run. It took about an hour from one terminal to the other, a distance of six miles.

Sentiment as to undesirableness of having this new means of conveyance pass one's door disappeared before the demands and stress of the times. People's minds were on other things than home comforts. The increased activity of all business now engaged in furnishing the sinews of war required more rapid conveyance between home and factory. In 1862 the restrictions against continuing down Chapel Street to East Street were removed, but it was not until the 1880's that the exclusiveness of Elm Street was overcome. In 1864 the line was extended out West Chapel Street to Norton Street and in 1885, due to the personal exertions of George D. Watrous, to the West River Bridge for the convenience of the new Yale Field patrons.

In the 60's the company did not limit itself to horse-car transportation. A bus service was run, but where I do not know, and stages and even sleighs were considered by the directors. This whole enterprise at its inception met the opposition of those who were operating stages. Injunctions were issued, and peace obtained in the orthodox way of settlement by purchase.

The new horse-cars, drawn, as one guide book said, by pairs of "elegant horses," became either so necessary or so profitable during the next four years that other companies entered the field. There was a real estate boom in the late 1860's that was the direct cause of some of these companies being started. The New Haven and West Haven was chartered in 1865, fare to Savin Rock 30 cents; and the New Haven and Centerville the same year to provide for the growing manufacturing concerns in the Dixwell Avenue district and the real estate development then occurring along

Shelton Avenue. The State Street Horse Railroad was chartered in 1868, and Sylvan Avenue and Whitney Avenue lines in the early 1870's. Many of these independent companies had their starting point at Church and Chapel Streets, and there was a time when at least four separate car tracks were located in the vicinity of that corner. Later these separate lines were all consolidated into one system, but this, together with the adoption of electricity and their extension farther and farther into the suburbs, does not come within the scope of a paper on the formative period of the undertaking.

Horse-cars were fundamentally only modernized stage coaches. There was nothing so new in their operation as to raise any difficulties. The great difference was that they operated on rails, and the effect of these rails on the street surfaces, together with the fact that the horses' feet always travelled in the same track, was recognized at the outset. The charter provided that the company should keep the roadway between the tracks and two feet each side in good and sufficient repair. At the very outset the space between the rails was paved with Belgian blocks. Grades were an obstacle that had to be considered. There were not many of them here, nor were they steep, but one extra horse was kept at State and Grand Streets and a pair at Chapel and Temple Streets to assist the cars, when heavily laden, up and over the railroad cut and up Chapel Street to College and High Streets. The rails were not the T rails that we know, but the so-called Philadelphia rail, strips of metal four or five inches wide with a raised ridge on the inner side on which the flanged wheels ran. These strips of metal were piked to wooden stringers that in turn rested on cross ties. I can remember the bitter complaints of those who were unfortunate enough to have their buggy wheels caught in these projecting rails and wrenched apart.

I hesitate to describe the cars. Some here must still remember them: small and low-swung, on four wheels under the center of the car, with seats running along the side, carrying about twenty-four; hand brakes; no enclosed platform, and at each end a cupboard with a kerosene lamp that supplied light within and without, generally smoked, and always smelled. In winter, straw was put on the floor to keep your feet warm, until coal, and sometimes kerosene, stoves were introduced. These added to the smell and somewhat to the comfort.

The motive power—horses—was such a common incident in the lives of so many, that no technical difficulties arose there. It all depended upon how shrewdly the purchases were made and how long the animals were serviceable, and Hoadley B. Ives could be depended upon in regard to both. When he came back from New York with a batch of ten horses, an extra one was generally found to be present. A horse was good for about six years. In the early days fodder came in from the surrounding farms without much difficulty. It was, however, a time of rising prices. Following an increase in fares to six cents in 1865, it cost twelve cents to ride from Fair Haven to Westville.

Economies were rigidly enforced. Some of this training in economy lasted well after this time. One of the officials, in his morning visit to the car barns, would regularly turn off the damper in the stove pipe to prevent the draft from burning too many of the old ties and horse collars that were used for fuel; and his satisfaction at having performed this duty was never upset by knowing that his employees had taken the damper out, so that when he thought it was off, it was really on.

The personnel of the horse railroad came into closer contact with the public than did that of any other company serving the public directly. The same people would take the same cars morning and evening to and from their work. There grew up between the crews and their patrons a certain sort of comradery, and, as many of the men were of marked personality, these daily trips became quite an incident in the city's social life. Richard Fellows, who lived at the corner of Humphrey Street and Whitney Avenue, one winter presented the drivers on that line with buffalo-skin coats; and in my day I can remember the Whitney boys taking the reins from Pat Foley and driving the car furiously out the Avenue. The speed did not, however, exceed twenty-five miles an hour. It was all a very friendly time. A mother with her baby would hail the driver. She and the baby would enter the car, and the baby-carriage would be hung over the back brake handles. The eight-horse snow-plow was always an exciting incident of the winter, and a subscription was levied on the passengers of all the cars they met to buy drinks for the snow-covered crews. The drivers would always convey and deliver a keg of beer from Buchholz on State

Street to Fair Haven for ten cents. S. E. Merwin would send hams to D. M. Welch at Grand and Front Streets for the same sum.

In the operation of the cars there developed a special technique that grew out of experience. To enter a crowded car for the purpose of collecting fares, it was often necessary for the driver to pull up on the reins and jam on the brakes, thus bringing the car to a sudden stop. After the passengers had unceremoniously obeyed the first law of motion the rear door could be opened. So reliable also was the motive power that the driver could hang the reins over the brake handle and enter the car to collect fares or to converse, without any interruption to the service. The passengers, too, developed their own technique. Thirteen passes were issued to the Yale team then performing their primitive athletics at Hamilton Park on Whalley Avenue. These they sewed into their hats, but, by some magic, fourteen were always found to be riding on the thirteen passes. During the skating season at Lake Whitney (signalled by a red flag in front of Bassett's hardware store) the roofs of the Whitney Avenue cars were occupied by some who technically were passengers. There were no Sunday cars until 1887. On Whitney Avenue a marvelous half-hour service was maintained, which dwindled to an hourly service in the winter.

I have mentioned these facts only in passing to give you a human picture of this formative period. It had a distinctly social aspect as far as the horse-cars went. It was not impersonal and hard-boiled. Everyone was a sort of partner in this new enterprise, from the "elegant" horses to the inebriate passenger on the last horse-car out at night. It is easy now to refer to any discomfort,—the combined odor of damp straw, smoky lamps, stale heat and packed humanity, alleviated by the devastating drafts when doors were opened,—but the whole venture was such a progressive move, and met such a need, that only the incorrigible few grumbled.

The barns stood on the site of the present car storage sheds on Grand Avenue, and during the summer months the atmosphere in that vicinity enjoyed a peculiarity all its own. At its peak 450 horses were stabled there, and that did not mean that the Fair Haven zephyrs were laden with the perfumes of Araby.

The same attention was given to the horses that a good engineer gives to his engine. Like the locomotives of the period that were stopped during the run for water, the horses halted at the city

watering troughs without regard to schedule or the convenience of passengers. And Dr. Adams, head of the Humane Society, kept his ears attuned to the bells around the horses' necks for any discordant sounds that would indicate lameness or exhaustion.

TELEPHONES

We now come to 1877. Dr. Paul Skiff has rented his opera house next to his residence on the south side of Chapel Street, just above Olive Street for a public demonstration by Alexander Graham Bell. This gentleman has a startling new device, by which the human voice, with the aid of wire and electricity, can be heard at a point far from the speaker, and he is going to show this unbelievable thing. People have heard of it ever since 1875, inspected it at the Centennial Exhibition in 1876, and it is occasionally being used between office and home, or friend and friend. Now for the first time New Haven is to see it in operation.

George W. Coy, who, the directory says, was manager of the Franklin Telegraph Company, but who also seems to have been with the Atlantic & Pacific Telegraph Company, both companies being in the Yale Bank Building at the corner of State and Chapel Streets, has arranged for the use of his company's wire connection with Middletown, and Tom Watson, Bell's collaborator there, talked and sang to the listeners in Skiff's Opera House. How many attended I do not know. But Coy was much impressed. If the wires from different sources could be brought to one central station, and a method found for uniting any one to any other, the problem of intercommunication would be solved. It was a grand idea. He asked for and got the franchise to use this new toy in New Haven in September 1877, after Fairchild of the Western Union had given it up. Then, from his own experience as a telegrapher, he, with much ingenuity constructed the first telephone switchboard in the world.

So far so good. But he needed financial and other help. It seemed like a pretty complicated thing to most people, even if it would work. There was also very great uncertainty as to how many could be persuaded to use it. Whom he went to among the well-known business men of the time and what banks he approached, I do not know. There were no religious scruples here, but plenty of practical ones, and I have been unable to find the name of a single well-known citizen as lending a helping hand.

A friend of his, engaged in the wholesale grocery business on State Street, Herrick P. Frost, caught his enthusiasm, however, and decided to risk \$600, which he borrowed of his friend, Walter Lewis, who the directory says was a watch-maker. Under some sort of voluntary partnership they started to operate as the New Haven District Telephone Company, probably in December 1877 or in January 1878. It was all very informal. We do not know of any articles of association or incorporation at this time. They rented space in the Boardman Building at State and Chapel Streets. All through the fall of 1877 Coy had been soliciting patronage. While it is a bit too early for me to have any personal recollections, I do know that very few gave any serious consideration to the telephone's convenience. In spite of the fact that Coy offered to install it with call-bell and wires for \$4.50 a quarter, New Haven had done its shopping, conducted its business, and performed its social duties too long by personal contact to have any confidence in this new way of doing these things. Strange as it may seem, the ministry has the credit of furnishing the first subscriber, Reverend Dr. Todd of the Church of the Redeemer. Twenty-one others followed, and the first commercial telephone exchange in the world went into operation on January 28, 1878. By February the number of subscribers had grown to fifty, and a directory was issued. It is an enlightening commentary on what New Haven thought of this new thing. The two subscribers in Fair Haven, Dr. Thompson and the New Haven Flour Company, were the only ones outside of the immediate vicinity of the original nine squares. Most of them were business houses. There are only eleven residences (New Haven had a population of about 60,000) and four of these were residences of members of the company. In March 1878 the list had grown to one hundred, and it was then thought that the natural limit had been reached. Again in 1886 the limit was thought to have been reached with 1,163. Between 1884 and 1894 the number hovered between 1,100 and 1,200. This slow growth was partly due to mechanical difficulties of which I shall speak later, for when these were overcome, the growth was rapid, until in 1930, the peak year, there were 52,000 subscribers.

Coy's switchboard was really a simple contrivance. Eight wires came in at the top, and there could be fifteen subscribers on each wire. A caller connected with No. 7 wire would push a button, and

the indicator on the upper right-hand corner would notify the operator by a clucking noise, which gave it the name of "Coy's chicken." The operator would throw No. 7 lever on the "listening bar" and find what person was wanted. He would then ring up the wire that this person was on. Everybody on the wire would answer, as there was no special signal or number for any particular persons until 1879. After he had tactfully eliminated (or thought he had) everyone except the desired person, the operator would throw the switch in the circle to knob 7 and in the next circle to, say, knob 4, if that was the wire, and the persons could talk to each other. Another call could come in and a connection could be made, but if a third call came while these two were being used, the subscriber had to wait, unless the operator was accommodating enough to wet his fingers and place one on each of the terminals, when the conversation would pass through his body. The board was even more personal than this, for some of the wires had been taken from the bustles that added so much to feminine beauty.

Since the transmitter and receiver were one instrument, the user had to remember to hold it to his mouth when talking and to his ear when listening.

There was only one wire, the ground being used for the return circuit, and with the introduction of the electric light and trolleys, both using the same return circuit, the "static" was bad. To radio users today this needs no explanation. You became more certain of a trolley going down Chapel Street, or that the electric street lights had been turned on, than of what your friend was trying to tell you. This naturally led to altercations with the other users of mother earth, to the considerable profit of the lawyers. It was only when two wires came into use about 1888 that this feature became a matter of history.

I remember also the household excitement when it was discovered that a wire had been strung across our backyard. Few poles were used, and, to reach a customer, trees and house roofs were used to support the wires, with or without permission. The desire to accommodate a neighbor did not always mollify the wrath over this flagrant aerial trespass.

The wire then used was soft and gave a great deal of trouble by sagging, until Thomas B. Doolittle, who long lived at Pine

Orchard, devised a hard-drawn copper wire that could be strung and kept taut.

A messenger service was instituted as part of the undertaking.

It is easy to understand that these first years were difficult financially. The pay-roll of two boys to handle the switchboard and an outside repair man who, after March 1, 1878, kept the exchange open all night, was a matter of concern. Patent suits, expenses of constructing and keeping up the lines, and insufficient capital, made any return highly uncertain. Then, too, in spite of all these drawbacks, the enterprise was growing. From the Boardman Building it went across the street to General Ford's Building, and from there to the Yale Bank Building, thus coming home to roost with the telegraph companies. Two ground circuit trunk lines to Hartford, Springfield and Holyoke were established in June 1878, and thus, besides being the first commercial telephone exchange in the world, the New Haven Company also became one of the first "long distance" lines. This was pretty fast going for such a financial weakling; but it had shown itself worth keeping alive.

By May 1878 a more definite legal status had to be considered. On the 28th the so-called New Haven District Telephone Company divested itself of all rights in the operation and installation of telephones to a new joint stock company for \$5,000 in stock. This new company, The Connecticut District Telephone Company, was organized with the help of Morris F. Tyler, a young lawyer who had been their legal adviser from the start and who had taken his pay in four shares of stock. Tyler later became president of the company, and treasurer of Yale. The articles of association of the new telephone company are dated June 3, 1878, its capital \$20,000, and Coy, Frost, Lewis and Tyler were its stockholders. A joint stock company composed of Coy, Lewis and a Mr. Hayward of Norwalk, called the District Telephone Company, was at the same time organized for \$5,000 to manufacture, buy and sell telephone and telegraph call-bells. On January 15, 1879, The Connecticut District Telephone Company changed its name to The District Telephone and Automatic Signal Company, with \$40,000 capital and 949 telephones. On May 20, 1880, it had reached an advanced adolescence as The Connecticut Telephone Company with \$100,000 capital and ex-Governor Marshall Jewell as president. Rivalry with Western Union had ceased in 1879. Connections could now

be had with Boston and New York by means of the new Interstate Telephone Company that had established an interstate line between Providence and Boston and later to New York. This was a Rhode Island company that Wilbur F. Day and Morris F. Tyler purchased in 1882, brought to New Haven, and had the Connecticut Telephone Company take over. The Massachusetts exchanges had been given up in 1880 and the company settled down to a respectable Connecticut existence. In 1882, T. S. Woolsey, W. F. Day, Thomas Hooker, Charles L. Mitchell and Marshall Jewell made it a full fledged corporation with \$500,000 capital, the present Southern New England Telephone Company, to be increased to \$5,000,000 as needed. Having so successfully reached maturity, it was entrusted with more and more Connecticut dollars, until today it is more broadly held by the public in its territory than any other of the Bell System subsidiaries. The blizzard of 1888 did give it a severe chill, but under the careful nursing of Morris F. Tyler, then president, who threw down his law-books and vowed he would put the company on its feet, and through the untiring efforts of its energetic general manager, Ellis B. Baker, it came to full manhood, as we now know it. Here is commercial romance of a high order right in our midst and within the lifetime of many present.

ELECTRIC LIGHTING

We began our talk with an account of the introduction of a more convenient and better kind of illumination in New Haven than any theretofore known. During the thirty odd years that followed, a marvelous change took place in the art of lighting. First the arc light, and later the incandescent lamp became practical. We close our evening with New Haven again courageously taking steps to profit by these new forms of illumination. In 1880 they were still in an experimental stage; they were uncertain and imperfect in operation, but they would work. Encouraged by the growing popularity of the new telephone, four of its sponsors, H. P. Frost, Morris F. Tyler, Wilbur F. Day, and Charles L. Mitchell became interested in this other electrical novelty. On April 12, 1881, these four, with S. E. Merwin, E. S. Greeley, E. G. Stoddard, H. H. Bunnell, C. W. Scranton, W. J. Atwater, Johnson T. Platt, L. P. Deming, F. A. Gilbert and Carlos Smith, all of New Haven, and Garrett S. Glen and W. H. Goodrich of Hartford, organized a

\$50,000 corporation (with right to increase to \$500,000), called the New Haven Electric Light Company, to manufacture and distribute this new form of light. Later Governor Bigelow joined them, and by October of that year they were able to circularize the citizens of New Haven, offering to supply them with lights from 16 to 2,000 candle power, generated by Weston and Maxim apparatus, and, further, to sell any of this apparatus to individual purchasers, to be erected by them in their own way and at their own expense. This offer was made possible by the company's acquisition of license rights for Connecticut from the United States Electric Lighting Company of New York. The latter company had just acquired by merger the results of Edward Weston's and Hiram Maxim's improvements of the dynamo and incandescent lamp, representing the latest arc light machinery and one of the most modern incandescent lamps of the time.

The company's dynamos and business were installed on the ground floor of the C. Cowles & Company plant on the east side of Orange Street near Crown, and the power was furnished by the boilers and engines of that concern, which were run after hours for its benefit. This makeshift arrangement must have existed for about a year, as the newspaper reports on December 20, 1881 that the company has taken a lease of the premises in the rear of the corner of Temple and Center Streets from Mrs. John W. Mansfield and expects to have its Corliss engines installed inside of four weeks. We have no records of those early days, and I have been unable to find anyone who remembers what took place. The business must have been entirely interior lighting in such central stores as Malley's, F. M. Brown's, Howe & Stetson's, and J. N. Adams', as there were no street lights until 1885, and the arc light of the period was not suited for private residences. In early December of 1881 two arc lights were set up to aid night work on the new New Haven Steam Heating Plant then under construction at the foot of Temple Street and attracted a crowd, a temporary and for the time a somewhat spectacular event. With the firmly established gas company satisfactorily supplying all the needs of the time, it was not easy to get customers. It was difficult to convey the direct current over any long distance. The arc light with its noisy sputtering carbons had to be renewed each day, and did not find favor. Maxim's incandescent lamp, improved as it

was by heating the filament in an atmosphere of hydrocarbon vapor, was costly. We do not know that any of these latter were used in New Haven.

On March 22, 1882 the company changed its name to the Connecticut Electric Lighting Company, probably anticipating a wider field of operation, or hoping to obtain capital outside of New Haven. E. S. Greeley was president, Herrick P. Frost, vice-president; Wilbur F. Day, treasurer, and George D. Miller, secretary.

During the rest of 1882 these officers must have had a difficult time. The business they obtained could hardly have paid expenses. I believe they did not have more than fifty lights, all in stores. In 1883 Charles H. Farnam became president, I rather assume because of his financial assistance, and the office was moved to No. 6 Temple Street, in property the company had purchased between George and Commerce Streets, while the plant remained at the old stand. Finally, after eighteen months of struggle climaxed by a suit brought by the United States Electric Light Company on a claim of \$800 for materials, the undertaking found its capital exhausted and itself burdened with an indebtedness of \$12,000; and in August 1883 it shut down completely. In the early fall of that year, Herrick P. Frost bought the now bankrupt and discouraged concern for \$2,500 and assumed all its debts. He had acquired machinery and personal property considered worth about \$35,000, real estate of \$5,500, and had assumed an indebtedness of from \$12,000 to \$17,000. He was probably not acting in an individual capacity.

On October 17, 1883, we find recorded articles of association of a new company using the same name, The New Haven Electric Light Company, and capitalized for the same sum, \$50,000. There were six subscribers to the stock: James English, F. A. Gilbert, A. Heaton Robertson, W. B. Hosmer, W. J. Atwater, H. P. Frost. F. A. Gilbert became president, James English secretary and treasurer, and these, together with H. H. Strong and Simeon E. Baldwin, constituted the board of directors. All the officers and directors served without pay. There must have been some connection between Frost's purchase of the old concern and this new one, and it was probably considered a feasible method of getting rid of the old company's litigation and liabilities. Only three of the directors had been connected with the old company; the remaining five were new men. That they acted energetically is evi-

dent, for by December 1, 1883 about seventy-five lights were again in use. They had contracted with the Thomson-Houston Company for a "one hundred light plant, engines and all electrical apparatus" for a sum not to exceed \$36,000, and on October 18, 1884, leased from George D. Miller a building in the rear of the Meyers & Hertz Shoe Factory on the west side of Temple Street between George and Crown Streets for five years at an annual rent of \$325, with privilege of renewal for five years at \$450. The new machinery was set up there and the business made a fresh start. The Weston system had been an utter failure. The property between George and Commerce was ultimately disposed of.

This Thomson-Houston system, with its self-regulating dynamos, gave a steadier flow of current than the discarded one, and the recent improvements in the incandescent lamps made them more reliable and cheaper to operate. All this tended from the start to increase the demands on the company. By 1884 the capital had to be increased to \$70,000 and more property leased from Miller and some purchased from Mrs. Anna Miller. Engines, boilers, and apparatus for fifty new lights were added, and the first contract made with the city for thirty-one street lights at 65 cents per night for one year. The gas lights were costing \$28 a year, but these thirty-one arc lights supplanted 107 of the gas. Two of these lights were actually installed in December 1884. A dividend of 2 per cent was declared on June 12, 1884, but not until English earlier in the year had told the Thomson-Houston people it could not be done unless they extended their note then due.

The current was a direct current, the only form then known, and passed directly to the arc lamps connected in series. There had to be a separate machine for each circuit. This meant four dynamos with twenty-five lights on each circuit. Even with their 200-horsepower engine, the field was limited. The street lights farthest from the plant at George and Temple Streets were at Orange and Grove, Broadway and York, State and George. The limit of the circuit was at Trumbull Street. There was no inside illumination after 12:00 o'clock. In spite of this the demand grew, and by 1885 the capital was increased to \$100,000 and more adjoining property was purchased from F. E. Spencer & Co. The equipment was changed so that instead of the lights for interior lighting being in series on a circuit, the divided or multiple system

was introduced. (Street lighting is, of course, still in series on a circuit.) This was a great step forward and kept pace with the improvement in the art.

In 1886 or 1887 came the incandescent lamp, which by this time had been so improved that it was quite practical for interior lighting, and, as the demand for it grew, the capital was again increased to \$150,000 and more land bought on George Street. By January 1, 1887, the company was burning 311 arc lights and 71 incandescent lamps, and on April 10, 1887, the joint stock company became the full fledged corporation that later, in 1899, when the Bridgeport Electric Light Company joined with it, took the name of The United Illuminating Company. The number of customers rapidly increased, and the capital was raised to \$200,000.

The industry had now taken a firm hold, and it was not difficult to dispose of its new stock. The quarters were still cramped. There was no storage room for coal, and the daily needs were met by one-horse dump carts, so that when the blizzard of 1888 came, the situation was serious. Every available man begged, borrowed or stole coal from the neighbors, carrying it to the plant in tin water pails, and English himself went to the Post Office and Trinity Church, and trundled coal down Temple Street in a wheelbarrow.

How rapid the growth now became is indicated by the fact that there were 421 arc lights and 3,852 incandescent lamps on January 1, 1889. But in spite of this showing, Atwater declares in his history of New Haven in 1888 that it is not believed that it will ever take the place of gas for interior lighting. This statement did not seem as unreasonable then as it does now. Considerable conservative inertia had to be overcome, and there was a good deal of reasonable and unreasonable prejudice. Whenever a fire of unknown origin occurred, it was laid to defective wiring. Rates were high compared to gas; wiring was expensive; service was not absolutely reliable, and was available only from 3:00 P. M. to 1:00 A. M. But further increase in dynamos, engines and apparatus had to be made, and the plant became so active that its neighbors began to register complaints. Crown and College Streets were then entirely residential. The constant vibrations of the engines and the continuous misty rain from the condensation of the steam were a constant annoyance. One night a little girl of about seven walked in with a sofa pillow soaking wet. She said it had

been out on the clothesline, and her mother wanted to know what in hell they were going to do about it. The number of houses that had to be periodically re-decorated was suspiciously large. While the location might be ideal as a distributing center, it did therefore have its drawbacks.

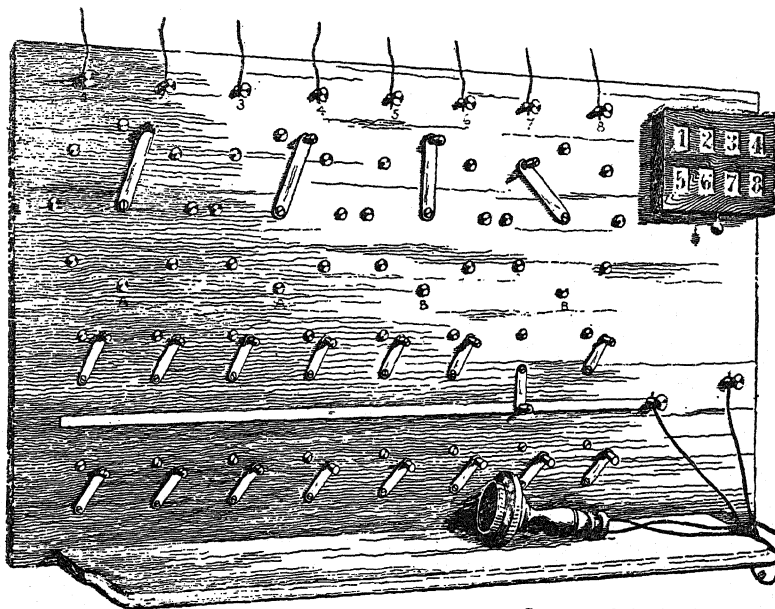
The undertaking had become one of major importance, and now came two very forward and important steps. English was convinced that all wires should be underground. It was true that the insulation of the wires was very imperfect, and some persons did not believe that it would ever be so improved as to make underground circuits practical. English persevered, as he felt sure that some form of satisfactory insulation would ultimately be found, and that the underground circuits would best be laid then to save greater expense later. He carried his point to the extent of having six circuits run under Temple Street to Chapel Street at an expense of \$4,907.20. Again the capital was increased to \$250,000, and English continued his campaign by proposing underground conduits on Chapel Street from Temple to State at a cost of \$7,000.

The other momentous change was the decision to rebuild the plant on the water front. The cramped quarters and cost of operating where it was, the constant complaints from the neighbors, with their threatened and actual law suits and the substitution of the alternating current for the old direct current, made such a move a necessity. Hence on May 2, 1890, was inaugurated, and on June 26, 1890, consummated, the acquisition of land in Grand Avenue where the power plant is now located. The capital was raised to \$300,000.

After the Grand Avenue plant was in operation, a further interesting development took place. New motor-generator sets to supply direct current were installed in the George Street plant, and these were run by the alternating current from the new plant. These furnished direct current to the center of the city until last year, 1937, when they were replaced by transformers. Now all current in New Haven is alternating.

A temporary scare occurred in 1895 when the Welsbach gas burner came on the market and the price of gas was reduced to \$1.25 per 1,000 feet; but this squall has been weathered, and Atwater's prediction has not yet come true.

We take for granted our gas, water, transportation, telephone and electric light, without a thought of the labors, anxiety, and difficulties that accompanied their birth. In the case of the telephone and electric light, this birth was almost co-incident with the birth of the art, and they have grown to their present stature with its growth. The sponsors of all of them have been our neighbors, members of the Yale faculty, and fellow townsmen. None of these utilities were born under the evil star of foreign parentage or absentee landlordism. No bar sinister of selfish greed or watered stock or undue self-aggrandisement appears on their escutcheons. It has been a clean, wholesome tale that I have been able to bring you, of initiative, courage and faith untainted by corruption or unworthy ambitions. If the stars did not sing together at their nativity, they have not had to look with shame upon their progress.



Courtesy of the S. N. E. T. C

The first telephone switchboard.

THE STORY OF THE FOUNDING OF THE SHEFFIELD SCIENTIFIC SCHOOL*

RUSSELL HENRY CHITTENDEN

DIRECTOR EMERITUS OF THE SHEFFIELD SCIENTIFIC SCHOOL

AS the first half of the nineteenth century was drawing near its close, there was growing in the minds of many thoughtful people a feeling that greater effort must be made to forward the material advancement of this country. Here was a vast, an almost untouched, continent, teeming with plant and animal life, a soil rich in the possibilities of great agricultural development, vast forests offering lumber in quantities beyond belief, mineral wealth of unknown magnitude, mighty rivers providing opportunities for water transportation, while developing steam transportation was promising rapid communication between distant parts of the country. Is it any wonder that in the minds of an energetic people there should arise visions of a development that might bring such a degree of prosperity as would make of this country a veritable paradise on earth. Such a setting and such people to deal with it, offered possibilities such as perhaps the world had never before seen.

But great wealth was wanting, and no less important was the lack of minds equipped with the needed knowledge and experience to outline and carry through plans for expansion and for the proper development of the resources so abundantly supplied. Progress, therefore, must necessarily be slow, unless means could be found to expedite matters. Engineers and scientific men in general were few in this country at that date, and such educational institutions as then existed were small and offered very little instruction in the sciences.

In Great Britain and in continental Europe, on the other hand, especially in France and Germany, there had been for many years a steadily growing appreciation of the importance of the sciences and a deep-seated conviction that there were many advantages to

* Taken largely from the author's *History of the Sheffield Scientific School*, New Haven, Yale University Press, 1928.

be derived from scientific culture. This belief had a natural foundation in the discoveries made by exceptional men, endowed with far-seeing vision, who through love of knowledge were seeking to enlighten themselves and others regarding the universe in which they lived. Many new and startling facts were brought to light, many new conceptions were created, and gradually among these countries of the old world there came about a more or less widespread application of these new scientific principles to the industries, to mining, metallurgy, agriculture, etc., which ultimately led to an industrial revolution. There grew up an enlightened appreciation of the value of science to the life of the nation, for the people saw clearly that science could be made the helpmate of industry with great advantage to the welfare of the country. The advances in the knowledge of science during the first half of the nineteenth century were indeed such as to awaken in the minds of thoughtful men a feeling akin to awe. The revelation of profound truths hitherto undreamed of, the new fields of thought opened up by the results of scientific research, the manifold ways in which these truths could be applied to the betterment of human conditions, all tended to elevate science to a position of supreme importance in the life of the world.

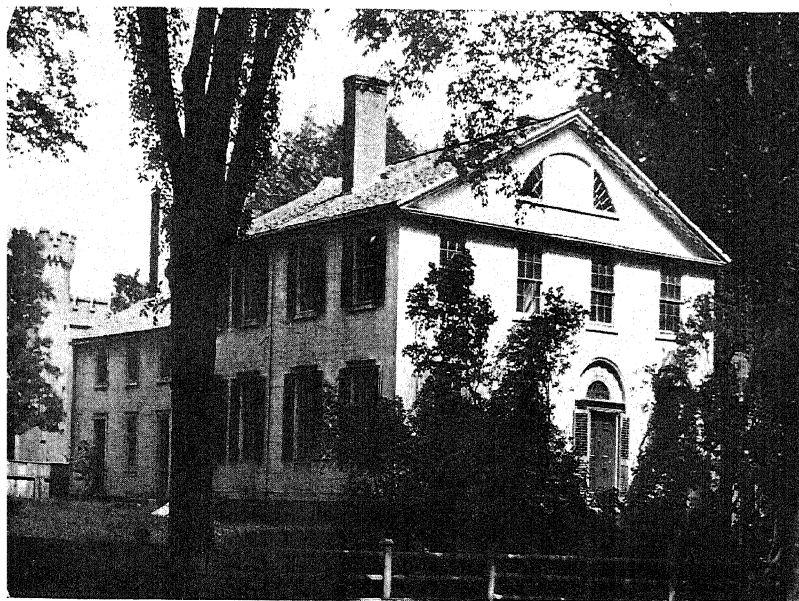
Consequently, in the European countries national support was freely given to the study of science. National societies and academies especially devoted to the cultivation of the sciences and to the encouragement of research were created and endowed. Of even greater importance was the establishment of scientific chairs in the universities filled by men of accomplishment in their respective fields of science, while polytechnic schools, schools of engineering, of mining, of arts and manufactures, of agriculture, of architecture and design, were created for the education of the people.

How radically different were the conditions in the United States in 1845. Education here, even in the oldest and most advanced colleges, was centered mainly around classical studies and was based on an established curriculum from which no deviation was allowable. There was a deep-seated aversion to new ideas, and science, so far as it was understood, was considered to be of relatively small importance and to have little educational value.

Further, this attitude of indifference and distrust was strengthened by another sentiment, especially conspicuous in this country,



John Pitkin Norton (1822-1852).



The Analytical Laboratory, about 1854.

one which for a time constituted a serious obstacle to the advancement of scientific knowledge. This was bound to a certain type of religious fanaticism, and so there arose scoffers who prophesied fearful disaster from attempts to peer into the mysteries of the universe, who even saw in the advance of science a menace to religious thought and religious belief. Studies in geology and biology were especially open to criticism and any statements bearing on the creation of the world and on the evolution of man not in harmony with the biblical story must be false and tending to destroy religious faith. Hence, the story of the rocks was to be discredited and biological study of man's origin was considered as fraught with moral danger. Therefore the study of science was not to be encouraged and this sentiment did in many quarters play a part in holding back the development of science in this country.

History shows that when unusual conditions arise calling for energetic action, wise leadership, or it may be for self-sacrifice, some volunteer frequently appears, ready and willing to assume the burden or the responsibility whatever it may be. In 1838 there was living in Farmington, Connecticut, a young man, then 18 years of age, John Pitkin Norton, of whom it was said that he possessed a philosophical turn of mind, "with an original genius for natural science" and manifesting in many ways an unusual inquisitiveness regarding all kinds of natural phenomena. He lived on his father's farm, studying winters in Farmington and New York. With no aptitude for the pursuit of Latin and Greek, his time was given mainly to the study of mathematics, drawing and French. But in the winter of 1840-41 he was at New Haven as a private pupil in attendance on lectures upon chemistry, mineralogy and natural philosophy in Yale College. Of the three following winters, two were spent as a private pupil in the laboratory of Professor Silliman, doing chemical work, and one in attendance on courses of lectures upon chemistry, anatomy, etc., at Harvard College.

He had no desire to enter one of the learned professions, but thought he would like to be a farmer and to this his father acquiesced, but with the one condition that he should be thoroughly and broadly educated as an agriculturist. At that date a specific education for the pursuit of agriculture was practically unknown in the United States, so in the spring of 1844 he went to Scotland where for two years he studied with Professor Johnston, the emi-

nent professor of chemistry, in the laboratory of the Agricultural Chemical Association at Edinburgh. In the spring of 1846 he returned to New Haven and it seems probable that the presence of this young chemist, a man of exceptional ability and unusual scientific training for those days, aroused in the mind of Professor Silliman, always zealous for the advancement of science, a feeling that in some way the services of so valuable a man should be secured to Yale College. There was another contributing factor, for at this same date a benefactor of the college, supposed to be young Norton's father, proposed to give \$5,000 for the endowment of a professorship of agricultural chemistry and of animal and vegetable physiology, provided \$20,000 be raised for that purpose. Yale College was poor, very poor, in those days and there was not much prospect of raising the required sum, and indeed it never was raised.

However, at the August meeting of the Yale Corporation in 1846, it was voted "that John Pitkin Norton be and he is hereby appointed Professor of Agricultural Chemistry and Animal and Vegetable Physiology, and that Benjamin Silliman, Jr., be and he is hereby appointed Professor of Practical Chemistry in this College." Attached to these votes was the statement that it is understood and provided that the support of these professors is in no case to be chargeable to the existing funds or revenues of the College, their compensation (if any) to be derived exclusively from fees for instruction and for other services.

Today this seems an unusual procedure. It certainly indicated caution combined with faith and hope in the future that was phenomenal. There was also implied a willingness to place upon the shoulders of these two young men a burden of responsibility such as few would be willing or able to assume, and yet these two men apparently assumed it gladly, with, I presume, a firm conviction that what they had to offer in the way of instruction in the applications of chemistry and the kindred sciences to agriculture and the manufacturing arts, to the exploration of the resources of the country, and to other practical uses, would in time bring a due reward.

After his appointment as professor of agricultural chemistry, Norton again went abroad and entered the laboratory of the celebrated Professor Mulder at Utrecht where he remained for the greater part of the year, devoting his time to experimental and

analytical work in chemistry, so as to fit himself more fully for his duties at New Haven. He could read French and German fluently and Dutch to some extent and so kept thoroughly acquainted with all that was being accomplished in the field of chemistry throughout Europe. He realized fully the extraordinary advantages of his situation, that probably no American had ever enjoyed his opportunities for scientific training in agriculture, and his devotion to his work sprang largely from a sense of duty. "He felt that he was now entering upon an extensive field of usefulness—that he was laboring in the service of his country—and that on his return he would possess a power for good which would perhaps belong to no other one of his countrymen."

The other appointee, Benjamin Silliman, Jr., had been graduated from Yale College in 1837 and for the succeeding nine years had served as his father's assistant in chemistry and mineralogy, so that he was by nature and training thoroughly equipped for the new chair of practical chemistry.

The first public announcement in 1847 of the new School of Applied Chemistry, as it was called, reads as follows: "Professors Silliman and Norton have opened a Laboratory on the college grounds, in connection with their departments, for the purpose of practical instruction in the applications of science to the arts and agriculture." This statement deserves a word or two of comment.

Today laboratories for instruction and research in all branches of science are to be found in practically every university and college throughout the land. No other method equals the laboratory method of instruction, in which the student, under proper guidance, studies and observes for himself the reactions and the facts upon which the concepts and theories of his science are based. The advantages are so self-evident, the training acquired in habits of observation so obvious, the power to draw logical conclusions from the facts gathered so plain, while the ability to recognize the difference between the truth and false ideas gives to the scientific method an educational value the importance of which cannot be over-estimated. All this is now so generally understood and practiced that it may seem superfluous to emphasize it here, but I do so because this laboratory of applied chemistry in 1847 was one of the earliest laboratories for practical instruction in a given science to be established in this country.

Laboratory instruction at that date was an innovation that

aroused in many quarters adverse criticism. There could be no educational value in methods and procedures carried on in what to the uninitiated appeared to be a very commonplace workshop, said the critic. How could mental growth and intellectual development be expected from such utilitarian-like methods. When the Sheffield Scientific School celebrated its fiftieth birthday, the orator of the day, Daniel Coit Gilman, then president of The Johns Hopkins University, in speaking of the early days said that Harvard and Yale caught the laboratory quickstep at about the same time; but Yale was a year ahead.

To return to the doings of the new "School of Applied Chemistry." The title sounds a bit grandiose and calls to mind a picture of something much greater than the reality. In the hands of the two men, Norton and Silliman, rested in large measure the fate of the new venture. Obviously in a school of applied chemistry much was required, in addition to the two professors, if students were to be attracted and properly cared for. The whole expense of carrying on the school had to be assumed by somebody, but there was no one disposed to take on the burden. As Professor Thomas R. Lounsbury wrote many years afterwards: "The College indeed had no money to give, but even if it had it is more than doubtful if it would have given it. No one at that time, however enthusiastic, ever dreamed of the supreme importance which the natural sciences were soon to assume in every well-devised scheme of education. The impression, indeed, seemed generally to prevail that chemistry, like virtue, must be its own reward." But John Pitkin Norton, the architect and master of the new school, felt differently, and he was ready to put forward all his energy toward the accomplishment of his desires, for he had a clear vision of a future for science in this country that would place the United States on a level with that of the countries of Europe.

When we speak of a laboratory today, we have a vision of an imposing building like the Sterling Chemistry Laboratory or the Sloane Physics Laboratory, for example, almost palatial in appearance and with an equipment of apparatus and appliances which represents large expenditures, all designed to care for the needs of hundreds of students, and with abundant facilities for advanced workers in research. How different in 1847! The laboratory opened that year was a plain wooden building, built in 1799, and

used for nearly half a century as the residence of Presidents Dwight and Day. This building, standing on the College square, facing the Green, occupying the site where Farnam Hall now stands, was rented from the College by Norton and Silliman, and at their own expense they transformed the interior into a fairly suitable laboratory. This building soon became known as the "Analytical Lab.", though generally called by the students the "Lab." The first year there were eight students enrolled in this School of Chemistry, while in the year 1848-49 there were eleven, and in the following year fourteen. Among these first students it is to be noted that George J. Brush, William H. Brewer and Samuel W. Johnson were enrolled, men who were destined to play an important part in the development of the Sheffield Scientific School.

One cannot help being impressed by the courage and faith of these two pioneer chemists, Norton and Silliman, when it is remembered that on their shoulders rested the whole financial burden of the laboratory, as well as the responsibility for the courses of instruction. The only source of revenue for meeting expenses and compensation for their services, aside from the interest on the \$5,000 donated for the establishment of the professorship of agricultural chemistry, was the tuition and laboratory charges collected from the students, a mere pittance compared with the cost of maintaining the laboratory. It is not strange therefore that in August, 1849, they presented a statement to the Corporation representing that the annual rent of \$150 paid by them for use of the building occupied as their laboratory was a heavy tax upon them, their expenses at the outset being large and their income small—and asking that hereafter they be given the use of the building free from rent, or for a mere nominal rent. This request was granted, subject to revocation whenever the Corporation might see fit.

The School of Applied Chemistry was now well started on its course, students were coming in increasing numbers each year, and they came because they were keenly desirous of absorbing such knowledge as was offered. They came with earnestness of purpose and with a degree of enthusiasm that kept the laboratory a beehive of activity. In those early days there were few or no rules or regulations. Freedom was the rule of the house, but the laboratory, poor though it was, was sufficiently attractive to hold the men

through all the working hours of the day and sometimes far into the night. The instruction they received was radically different from the usual type of classroom work. It was mainly personal contact in the laboratory, where students worked out for themselves chemical reactions, determination of the composition of unknown compounds and in various ways gained first-hand knowledge of the facts and principles upon which chemical laws are based. In a sense each student was an investigator, feeling his way carefully along unfamiliar paths, gaining strength and confidence as he progressed, and acquiring habits of self-reliance and the power of drawing sane and safe deductions from observed facts. The professor was there to guide and advise, not to drive along an unattractive path, and hence there was engendered a freedom of thought and action conducive to mental independence.

If I seem to dwell unduly upon these matters, it is because in this simple laboratory there were being developed methods of instruction, unique at the time, that were in later years to become common property and followed wherever instruction in the natural and physical sciences was offered. At that date, however, no one gave any thought to the new school. Methods and procedures attracted no outside attention. The two professors were left very much to themselves, to do as they saw fit. To quote Professor Lounsbury again: "No one in particular either helped or hindered the growth of the school; indeed outside of those immediately and specially interested in it, no one troubled himself about it at all."

The faith of Norton, however, was proof against any and all obstacles and at this time he needed all the faith he possessed, for toward the close of the year 1849 Benjamin Silliman, Jr., withdrew to become professor of chemistry and toxicology in the Medical School of the University of Louisville. He disposed of all his interests in the analytical laboratory to Professor Norton, thus leaving the latter solely responsible for the continuance of the School of Applied Chemistry. Obviously, Norton could not for long carry it on alone. The financial burden he might be able to bear, for he had very substantial means at his command, but if the scope of the school was to be maintained and enlarged, there must be considerable increase in the teaching staff. With the help of one or two young assistants, however, he went on alone arranging for a little more formality in the curriculum and with somewhat broader

scope, together with final examinations to measure the extent of the students' accomplishments.

In 1850 he presented to the Corporation a request that the degree of Bachelor of Philosophy be instituted, to be granted to such students as shall have resided for two years at the College and have pursued their studies for nine months in each year, followed by a successful examination in three branches of study, with proficiency in either the French or German language.

On commencement day 1852, six of the eight men who had completed a course of scientific study covering the specifications approved by the Corporation were granted the degree of Bachelor of Philosophy and thus became the first graduates of the Scientific School.

During the five years Professor Norton had been active in the School of Applied Chemistry he had likewise been concerned in ways to provide superior and scientific methods of agriculture in this country. With this in view he devoted all the time he could spare from the laboratory and lecture room, his pen, voice, purse, time and influence, all being used to further this end. He wrote freely for the agricultural journals, he spent time lavishly in travelling about the country giving addresses before agricultural societies; he prepared several memoirs dealing with special topics in scientific agriculture, all with the purpose of stimulating interest in the applications of science to the cultivation of the soil. He was truly a pioneer, being one of the first in this country to demonstrate through his own work the high office of the scientific man in relation to agriculture.

But all this work was gradually undermining Professor Norton's health. His last services for the School consisted in the examination of the several candidates for the new degree. On September 5, 1852, just prior to commencement, he died at Farmington, in the home of his father, at only thirty years of age. He was truly a martyr to the cause of science. Such success as the School had enjoyed was due almost entirely to his ability, energy, self-sacrifice and a devotion that never flagged, no matter how great the difficulties confronting him. Almost the last act of his life was to give to the College all the apparatus of the laboratory, his books, manuscripts, chemicals and other articles, subject, however, to the department's being continued and, he added "I hope it will be kept

up; it has cost me a great deal of labor." So ended the life of him who above all others deserves the title of "founder." Such a school as he envisaged would have come eventually under any circumstances, but it would not have come at this early date had it not been for John Pitkin Norton.

For a time the fate of the School hung in the balance; there was no money available to render a professorship attractive and, furthermore, there was no possible candidate in sight who gave promise of meeting the conditions that existed. There was one man, however, who finally appeared as a possible successor to Norton, John Addison Porter, a graduate of Yale College in the class of 1842, a man of great natural ability with a highly developed literary taste. After several years of experience in teaching rhetoric at a small college, his thoughts began to turn toward science and he finally went to Germany, spending two years with the renowned chemist, Justus von Liebig, where he acquired not only a broad knowledge of chemistry but also a high appreciation of the importance of agricultural chemistry, for Liebig had in Germany and elsewhere demonstrated the benefits to be derived from the more scientific treatment of the land and in the cultivation of crops.

Porter welcomed the opportunity of taking up and carrying on the work inaugurated by Norton. It proved to be a wise choice, for Professor Porter, like Professor Norton, was possessed of a personality that endeared him to those with whom he came in contact and rendered him an admirable leader, and to him was due in part at least the effort made early in the life of the School to impart a broader culture than could be attained by training in any one special line of study.

The Corporation was impressed by the number and character of the students seeking admission to the School of Applied Chemistry. Consequently when a proposal was made in this same year, 1852, to establish a course in another applied science, engineering, they were disposed to consider it favorably. Here, we have essentially a duplication of the conditions that obtained when the School of Applied Chemistry was started in 1847, namely, a proposal to open a "School of Engineering" to be sustained at the expense of the applicant, he to provide all the necessary apparatus and to receive in return such emoluments as might be derived from the students.



*Joseph Earl Sheffield (1793-1882)
original portrait by Julius Hübner,
Dresden, Germany, 1857.*



Sheffield Hall, 1860-1866.

This astonishing application was sponsored by the elder Professor Silliman and in due time, July 27, 1852, at the annual meeting of the Corporation it was voted to establish a new professorship to be called the professorship of civil engineering, William Augustus Norton to be the incumbent. Here again it was made clear that any department of study originating from this action must be self-supporting, or at least that none of the funds of the College could be applied in support of this professorship. The question naturally arises as to what sort of a man was this William Augustus Norton and why should he be willing to enter on what appeared to be such an unprofitable undertaking?

Professor Norton graduated from the United States Military Academy in 1831 and was immediately assigned to duty as acting assistant professor of natural and experimental philosophy in the Academy. After two years of service there, he filled several teaching positions in mathematics and civil engineering in various colleges, coming in the fall of 1852 to Yale, where he remained for 31 years. Professor Norton was a man of great personal charm, combined with a strength of character that made him an outstanding figure in the early years of the Scientific School. He was a scholarly man, widely read in fields far removed from his own line of work, with sympathetic interest in all branches of knowledge.

He evidently, like John Pitkin Norton, felt that here at Yale was a wonderful opportunity for the advancement of a branch of science that promised great aid in the development of the material resources of the country. But he must have had a full measure of faith and confidence for there was nothing but what he himself could bring to foster growth and expansion, except perhaps the name of Yale which carried a certain assurance of sound scholarship and a scholarly environment. And Norton was a scholar, seeking to advance his science by hard thinking and diligent effort, as evidenced by his many contributions, published in the leading scientific magazines and journals of his time, which brought him well deserved recognition in the scientific world.

At this date, 1852, there was no school of science as such, but two distinct schools, one the School of Applied Chemistry, the other the School of Engineering, each under its own specific management, while both were parts of the so-called Department of

Philosophy and the Arts, created in 1847, with the intent of making a place in the college scheme for graduate students and others who might desire instruction in particular lines beyond what was wanted or could be given in the regular college course. This establishment of the Department of Philosophy and the Arts, created primarily to make a legalized place for the School of Applied Chemistry was theoretically at least a distinct step forward in the United States, since it was the formal beginning of graduate or advanced instruction along special lines, not covered by the colleges or the professional schools. For many years, however, this new department rested almost entirely upon the School of Applied Chemistry and the School of Engineering, the two together constituting the embryo of the future Sheffield Scientific School. The enrollment of the two schools for the college year 1852-53 was certainly impressive; 25 in the School of Chemistry, 26 in the School of Engineering, while the so-called Department of Philosophy and the Arts numbered a total of 55, leaving only 4 students pursuing general courses, outside the two schools. Further it is interesting to note that of these 55 students, 16 were graduates of colleges, having the bachelor's or master's degree.

The college year 1852-53 marked a distinct advance. The School of Chemistry and the School of Engineering, the latter housed on the fourth floor of the College chapel, formerly used for the library, were both moving forward in definite fashion and under Professor Porter the School of Applied Chemistry was offering a systematic plan of work especially for the beginners. Observers in the College world saw that here was the beginning of a new order. There was manifest evidence that there was a distinct demand for the courses offered. Chemistry and engineering were only two branches of scientific study and even those critically minded began to wonder what would happen if other branches of science were introduced, taught by the same methods in the laboratory, drafting room, and in the field, where the student was compelled to depend in large measure on his own initiative, stimulated or restrained as the case might be, by the instructor. Plainly, there was much food for thought here, but there was no money available and few men qualified to serve as professors or instructors could be found willing or able to rely upon the uncertain fees of students as their sole source of income.

The College, however, was becoming interested and perhaps a little proud of the accomplishments since the beginning of the School of Applied Chemistry in 1847, and in the college year 1854-55 the two schools were grouped together under the title "Yale Scientific School." This name is naturally suggestive of a concrete institution with some marked individuality, but in reality there was no change in existing conditions, the actual merging of the two not coming until some years later. The only significance in the new name was that it served to mark a distinct separation of the sciences from the other subjects embraced under the Department of Philosophy and the Arts, although it is possible that it was also a gesture to encourage science and give it a more definite position.

However this may be, there was no substantial gain involved in this change of name and no hope of any immediate improvement in existing conditions. Certainly without funds it did not seem safe to undertake any expansion, but there was courage in the hearts of Professors Porter and Norton and I fancy the increase in the number of the students gave added courage, for in 1855 they felt it safe to venture on the establishment of a chair of metallurgy, being of the opinion that a course of instruction in mining and metallurgy would be of great service to the country in aiding the development of its mineral resources. Whoever may have been responsible for the selection of the incumbent of this chair, he or they picked a man who for more than fifty years served the School in a manner that brought credit and distinction to the institution as well as to himself. In July 1855 the Corporation voted to create a professorship of metallurgy and appointed George J. Brush to fill this office.

Professor Brush was one of the earliest students of the School of Applied Chemistry, graduating with the first class to receive a degree in 1852, having absorbed all the chemistry and mineralogy then available. He then went abroad, spending one year at the University of Munich, one year at the Royal Mining School of Freiburg in Saxony, and one year at the Royal School of Mines, London. These are points worth noting, for they testify to the exceptional quality of the men chosen to carry on the work of the school. The best scientific training available was prerequisite and two or three years of study at the famous universities and schools

of science abroad gave, at that date, the best opportunity for the acquisition of profound knowledge that could be obtained anywhere. It was an exceptional training for a young American. He continued abroad until 1857 when he took up his work at New Haven. His work in the Scientific School was far reaching; as a mineralogist he gained a reputation that grew with the years, bringing to the School recognition as the one place in the United States where that particular science was being developed in striking fashion. After the death of Professor Porter he became the leading spirit of the faculty, guiding the institution wisely in its growth and development. As treasurer, he saw to it that every dollar was expended to the best advantage and throughout his long period of service he was a tower of strength, and a counselor in whom all had confidence.

In 1856, a year before Professor Brush appeared, another appointment was made, likewise significant and in line with future expansion. The vote of the Corporation at this time is rather suggestive, since it reads: "Voted: by recommendation of the instructors in the Scientific School, that Samuel W. Johnson be elected professor of analytical chemistry." This vote recognized the existence of a distinct board of instructors of the Scientific School, of sufficient standing with the Corporation for a recommendation from them to be given serious consideration. It is also worthy of note that, as in the case of the previous appointments, the votes for both Brush and Johnson carried a statement that the funds of the College were not to be used for the support of these professorships. Professor Johnson, like Professor Brush, was one of the earliest students of the School of Applied Chemistry, and directly after graduation he went abroad, studying chemistry at the University of Leipzig and also one year with Liebig at the University of Munich. Here he became greatly interested in the applications of chemistry to agriculture and acquired that knowledge and enthusiasm which eventually led to his becoming the master mind in the development of the agricultural experiment stations of this country.

Ten years had now elapsed since the initial efforts of Norton and Silliman and over 300 students had taken advantage of the opportunities offered. Here many of the best young chemists of the land had taken their first steps in science. The ten-year period

that had passed was a test period. The plan had certainly justified itself and the evidence appeared conclusive that, given suitable conditions, a comprehensive school of science of high character could be established. But it was a new form of education in this country at that date and while there was more or less interest, nothing substantial was offered.

Still Porter, Norton, Brush, and Johnson had vision, and they dreamed dreams of what might be accomplished, could sufficient money be found to furnish the necessary endowment. They felt the time had come for a vigorous and determined effort, if what had already been created was to be maintained, and further expansion provided for. Several pamphlets or appeals were issued, hoping to gain the interest and cooperation of some of the wealthier people of the community. One of the most interesting appeals, 1856, was signed by Professors Porter, Norton, and Brush, and also signed by Theodore D. Woolsey, then president of Yale College, Benjamin Silliman, then emeritus professor, and James D. Dana, Silliman's successor as professor of geology and natural history in Yale College, which gave added dignity and strength to the appeal.

We can gain an idea of what was in the minds of these people, what the character of the institution they envisaged, by quotation of a single paragraph from the appeal. "The plan we contemplate would include mathematics to its highest departments and through its various applications; the different branches of physics and chemistry; geology in its grandeur as a record of the past, and also its developments respecting mines, building materials, and soils; astronomy; mineralogy, zoology, botany; the logic and philosophy of the inductive sciences, modern languages, and their connection and origin; geography in its relation to climate, history, commerce, and the progress of nations; drawing and the history and criticism of art; all these besides the practical arts and sciences in their diversity.—The plan so blends the departments of knowledge taught that the student, if he remains long enough to take the benefits offered, will come forth, not shaped only for a single narrow channel of life, but with cultivated intellect and broad views of the world." Truly an ambitious plan, which to most people looked like a sort of pipe-dream hardly worthy of serious consideration.

Along with these general appeals and statements were issued individual pamphlets from the four professors making clear the purpose of their respective courses. Thus, Professor John A. Porter outlined a plan of an Agricultural School calling attention to the fact that "we are to a great extent a nation of agriculturists yet without an institution in the whole length and breadth of the land which furnishes the proper instruction to the agricultural community."

In response to these various appeals a few contributions of money came in, largely from residents of New Haven. Thus, Joseph E. Sheffield gave \$10,000, Oliver F. Winchester \$5,000, while a number gave \$1,000 each, among these Eli Whitney, Augustus R. Street, Wells Southworth, James E. English, President Day, Joseph Battell, and Joseph Sampson. While these liberal donations were encouraging, they were obviously not sufficient to afford more than a temporary relief. What must be secured was an endowment fund sufficient to insure stability and permanence, otherwise all the plans and all the hopes centered in the enterprise would fall to the ground. It is easy to imagine the feelings of those pioneer workers, especially William A. Norton, Porter, Brush, and Johnson, who had staked everything on a venture which they believed in and who now had tangible proof that success was assured, if only adequate financial support could be obtained. The goal seemed so near, yet this lack of substantial response to the many pleas made gave cause for doubt and depression.

Help, however, was close at hand, Mr. Joseph Earl Sheffield, who had already shown some interest in the School, now came forward with a proposal that must have seemed to those most interested as the direct manifestation of a kind Providence working through a generous-minded man. The proposal was very simple, but it carried with it an assurance of security and put new courage into the hearts and minds of those who were to bear the burden of future development. Mr. Sheffield's proposal was to provide a suitable building to house the several departments of the School and a permanent fund for the maintenance of professorships.

Mr. Sheffield's interest in the School of Science was probably of two-fold origin. Professor John A. Porter had married one of his daughters and this naturally drew the attention of Mr. Sheffield to the School with which his son-in-law was connected and

doubtless its obvious needs called forth his sympathy. But there was another reason, perhaps even more potent which should not be overlooked, for it probably explains in large measure the continued interest he displayed up to the end of his life. He had been active for many years in promoting the construction of railroads throughout the country. He was one of the early pioneers in this field, and consequently he had a very keen appreciation of the value and usefulness of the engineer in these large projects which were to play so important a part in the future prosperity of the country. To such a man, a school of science, where young men could be trained in the essentials of engineering, in the mechanics of machinery, in the chemistry of materials, must have appealed strongly. For he was a man of farsighted vision and he saw, as few others did, how such a school might prove of inestimable value in helping to make available the resources of the country for the good of the people. He was exceedingly generous, broad-minded, and sympathetic, but above all he was a keen business man who did not give his money unless convinced that it would be used to good purpose. Hence, his beneficent action constituted a stamp of approval that went far toward placing the school on a different level in the eyes of the community.

In October, 1858, he purchased the large stone and stucco building known as the Medical Institution, on Grove Street, at the head of College, refitted it throughout and increased its capacity by two large wings. Having completed the building, Mr. Sheffield quickly realized that much was needed in the way of equipment, and he proceeded to supply this need by the purchase of a large amount of apparatus such as was required in chemistry and in engineering. The building, known as Sheffield Hall, was ready for occupancy in 1860 and the two schools of chemistry and engineering moved into their new quarters under the same roof and thus for the first time became truly united. The future of the Yale Scientific School now seemed assured. It had a home of its own without encumbrance of any kind; it was provided with the most approved apparatus and instruments for both instruction and research; it possessed extensive mineralogical and metallurgical collections and, further, it had an endowment fund that for those days seemed large. In 1861, the Corporation, in view of Mr. Sheffield's great munificence, gave to the School the title "*Sheffield Scientific School*", by which name it has been known from that time on.

The permanence of the School being assured by Mr. Sheffield's proposal, the faculty began at once, before the new home was ready for occupancy, to plan definitely for the future. Thus in 1859 there was established a professorship of industrial mechanics and physics, the Corporation appointing Chester S. Lyman to that position. Later his title was changed to "Sheffield Professor of astronomy and physics." For 30 years Professor Lyman served the School faithfully and well, and the memory of his tall and commanding presence, with the kindly expression which was an outward sign of the kindness of his heart, still remains in the minds of many graduates who came under his instruction and guidance.

This same year saw another addition to the faculty of the School which was of special significance. For the accession of William Dwight Whitney, one of the foremost linguistic scholars of his generation, as professor of modern languages, not only provided the needed instruction in French and German, but brought into the faculty a man of rare judgment, whose counsels and influence were of great value for a period of 34 years. There was need of such a man in those early years, when the small faculty was composed entirely of scientific men, for highly specialized work in a given field frequently leads to a restricted perspective.

Another appointment in 1863 that likewise added greatly to the general strength of the School was that of Daniel Coit Gilman as professor of physical and political geography, a field of work broadened later to include history and political economy. His zeal, his ability, his untiring energy and his fertility of resources made him a pillar of strength upon which his colleagues relied in times of storm and stress, and, it may be added, such times were of very frequent occurrence. He was especially active in bringing before the people of the state the significance of the new education, emphasizing the view that scientific schools were a logical indication of the spirit of the age, a manifestation of the desire for an advanced education on some other basis than the literature of Greece and Rome.

With Professor Brush he was exceedingly active in the search for the money needed to support the School, which was increasing far more rapidly in numbers than in wealth. Wherever and whenever he could gain an audience, he told the story of the School and its needs, sometimes in lecture rooms, frequently in private par-

lors, once in the Governor's Room at Hartford, and once in a fire-engine room, with earnestness of conviction if not with the grace of eloquence, and with the certainty, not of history, but of prophecy. After nine years of labor in the interests of the Scientific School, Professor Gilman went to California as president of the University of California, and in 1875 he became the president of the newly established Johns Hopkins University at Baltimore.

Probably the most important event, historically, in these first years of expansion was the establishment of more advanced courses of scientific study with the institution of the degree of Doctor of Philosophy. This came about as the result of a memorial presented to the Corporation by John A. Porter, as dean of the Faculty of the Scientific School in 1860. So was inaugurated a movement in this country, the beginning of so-called university development which has spread to the uttermost parts of the land and resulted in the expansion of higher educational training to a degree never even dreamed of at the time. In the words of President Gilman, "Yale and Sheffield are entitled to the credit of introducing among American institutions the degree of Doctor of Philosophy, demanding for it a high standard of attainment and never bestowing the honor by any irregular promotion."

In 1862 another expansion was in the air. That year the United States Congress passed an "Act donating Public Lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts." Thus were inaugurated the Land Grant Colleges or State Universities, now so powerful a force in the education of our people. Congress, however, had specified several conditions regarding the use of the funds coming from the sale of the land-grant scrip, viz., that the State claiming the benefit of this Act must provide at its own expense all necessary buildings and equipment, meet all expenses for maintenance and repairs. Further, no part of the fund could be expended, only the annual income, and this could be used solely for meeting the costs of instruction. The State of Connecticut was not willing to assume the heavy burden these conditions called for and in 1863 the Judiciary Committee of the State Legislature and representatives of the Faculty drafted a bill, passed by the two branches of the General Assembly, by which the Sheffield Scientific School became the land-grant college of Connecticut, and obligated

to furnish gratuitous education to a specified number of students from the State. The lands assigned to the State were sold for \$135,000, or seventy-five cents an acre, and the income from this fund was paid semi-annually for the benefit of the Scientific School. As a result, 43 free scholarships became at once available for students from Connecticut.

This called for immediate enlargement of the curriculum. Courses related to agriculture were given first consideration. Professor Porter, who had been very active in this field, was in failing health and indeed found it necessary to resign his professorship in 1864. Four years later he died at the age of forty-four years. Professor Johnson plainly could not carry the burden alone and another competent man must be sought for. He was found in the person of William H. Brewer who was appointed Norton professor of agriculture in 1864.

Professor Brewer was a member of the first class to graduate from the School of Applied Chemistry, after which he went to Europe, perfecting his knowledge of chemistry and other related sciences by one year at Heidelberg with the renowned Bunsen in chemistry and with Schmidt in botany, a year at Munich with Liebig and six months at Paris studying chemistry and botany. He was thus broadly trained and on returning to this country he was for four years with Professor J. D. Whitney making a geological survey of the State of California, thus accumulating a knowledge of the geology, geography and botany of that state. Such was the training and experience of the man who was destined to exert a powerful influence upon the scientific life of the New Haven community, for Brewer, with his great versatility, breadth of sympathy, keen judgment and far-sighted vision was not content to confine himself to purely academic matters, but must needs reach out a helpful hand in many directions.

For this very reason he was an ideal man for the professorship of agriculture, since his duties could not be confined to the classroom or laboratory, if he was to bring the advantages of scientific agriculture to the attention of the farming communities of the state. There was no one who could arouse the interest and hold the attention of a public audience as Brewer could; consequently he was an invaluable representative of the School before any body of people, whether the State Legislature, the State Board of Health,

the Connecticut Agricultural Society, or a national commission. He was active for the betterment of public health and for the advancement of agriculture, especially in Connecticut, for a proper topographical survey of the state, for the preservation of the forest resources of the country. He had 39 years of active service and his help and influence cannot be measured in definite terms, so great was the catholicity of his interests.

Two other professorships were established at this same time in order to meet the demands for a broader curriculum, viz., Daniel C. Eaton as professor of botany, and Addison E. Verrill as professor of zoology. Professor Eaton studied botany with Asa Gray at Harvard and came to the Scientific School in 1864 with a rare knowledge of his subject. For 30 years he labored to make this a center of scholastic activities in his chosen field of science. He made many and varied scientific contributions to botanical knowledge and on his death he left to the University his private herbarium, one of the largest in the country, together with his exceedingly valuable library containing many old and rare books on botany.

The appointment of Professor Verrill brought to the Scientific School a man who was to become pre-eminent as an investigator in invertebrate zoology. He had studied under Louis Agassiz at Harvard and had a broad training in this subject. He was more of an investigator than a teacher. When the United States Commission of Fish and Fisheries was organized in 1871 under Professor S. F. Baird, Professor Verrill became actively associated with the work, taking charge of the deep-sea dredging of the Atlantic and eventually of the Pacific coasts of North America. Collecting in this way, through many years of work, innumerable specimens of the deep-sea fauna, his descriptions of new forms of invertebrate life filled many volumes and gained for him a high position as a scientific investigator in marine zoology. For 43 years he served the Scientific School and built up a strong department of zoology in this University. As President Hadley wrote in 1907: "Professor Verrill is the last of the group of men whose names were associated with the early struggles of the Scientific School in the days when the claims of science were but scantily recognized by the country and when the future of the School itself was somewhat uncertain."

In 1866, Mr. Sheffield, ever watchful of the steady expansion of the School, saw quite plainly that the building was becoming inadequate for the needs of the institution. He proceeded, therefore, wholly on his own initiative, to make such additions as the general character of the building would permit, so as to give additional space and increased facilities for work. A three-story structure was built connecting the two wings of the building, a projecting tower, 90 feet high, was erected in front, while on the Prospect Street side another tower was built, 50 feet high. These two towers were not for architectural effect, but were for a very useful purpose. On the principal tower, above the belfry clock, was a large revolving turret, in which was mounted a ten-foot equatorial telescope, while on the second tower was a meridian circle provided with a five-foot telescope. With these two instruments, so suitably mounted, and with many accessory pieces of apparatus, the astronomical work of the School was now arranged for in a very satisfactory manner. Further, the three-story addition to the building gave increased space for the chemical laboratories, needed lecture rooms and a large library room. Mr. Sheffield also provided a library fund. It is interesting to note that in a publication issued at that time (1866) the statement is made that this building as it now stands, "is believed to be the most complete of its kind in the country."

No better evidence of the deep interest which many of the citizens of New Haven took in the growing School can be offered than the simple statement that, learning of the immediate need for books, eight people came forward with voluntary contributions of from \$100 to \$500, making a total of \$2,000 to be expended at once for books of reference. Four years later, in 1870, Mr. Sheffield again manifested his interest in the library by purchasing at an expense of many thousands of dollars the valuable and celebrated Hillhouse Mathematical Library. The collection was catalogued by the School and printed copies sent to the large libraries of the country, and, as a result, many of the rarer volumes, not elsewhere obtainable, were frequently consulted by expert workers in the field of mathematics.

In 1866 the Governing Board of the Sheffield Scientific School requested the establishment of a distinct chair of paleontology, recommending Othniel C. Marsh as a suitable incumbent. This the

Corporation voted, thus bringing into connection with the work of the School a man who was destined to become one of the foremost scientific men of America, and who was to enrich the science of paleontology by discoveries of great and broad significance. It is worthy of note that this was the first professorship of paleontology to be established in this country, and I believe the second time such a distinctive title had been given anywhere. To Professor Marsh, who was the nephew of Mr. George Peabody, of London, must also be ascribed an influence which in part at least was responsible for the establishment of the Peabody Museum of Natural History, from which the people of New Haven and nearby communities have so greatly profited.

In 1870 an advance was made in engineering by the appointment of William Petit Trowbridge, a graduate of the United States Military Academy at West Point in 1848, as professor of mechanical or dynamical engineering. In this connection the statement was made that "this is the first instance in this country in which an institution of learning has adopted a systematic course of instruction having for its objective *exclusively* the preparation and training of young men for the pursuit of this comparatively new profession."

In the following year, 1871, Thomas Raynesford Lounsbury, a graduate of Yale College in 1859, and a veteran of the Civil War, was appointed professor of the English language and in 1872 General Francis Amasa Walker was appointed professor of political economy and history, two appointments that speak clearly of the efforts of the School to expand instruction along cultural lines. For a period of 36 years Professor Lounsbury was a power for good both in the Scientific School and in the University. He was a conspicuous figure among that strong group of men who helped to shape the policy of the Sheffield Scientific School. He made most notable contributions to literature and scholarship, and was the author of many books and essays. To him a multitude of students owe the love of good literature acquired during their college course.

Professor Walker was a "pioneer in the sciences of economics and statistics and a master of scientific method" and the Sheffield Scientific School was extremely fortunate in securing such a man for the new chair. He possessed a quick and searching intellect, an unusual gift of expression, and a judicial type of mind that

enabled him to separate the essential from the non-essential in a statement of facts or a body of argument. Moreover, he was courageous, both in the holding and in the pushing of his opinions, and was always zealous to make his unusual powers of the largest service to society. He took an active and influential part in the affairs of the School during his nine years' connection with the institution. It is significant that Professor Gilman and Professor Walker each left the Scientific School to assume the presidency of another educational institution, Professor Walker going to The Massachusetts Institute of Technology.

It is clear that effort was being made as speedily as possible to put in practice the plan outlined in the plea of 1856, viz., to create a scientific school that should have breadth as well as depth, hence the appointment of such men as Gilman, Whitney, Lounsbury, and Walker; men who through their respective fields of study would contribute a broadening influence, thus preventing the students from becoming too narrowly specialized.

In the spring of 1872 work was commenced on a new building, North Sheffield Hall, a further donation from Mr. Sheffield. While deficient in the grace and beauty that characterizes the modern college building it was a large and substantial structure well adapted to the needs of the School, and its erection marked another epoch in the growth of the institution.

Twenty-five years had passed since the School of Applied Chemistry had started in 1847. The vision of John Pitkin Norton had been more than realized, what had seemed to most people a mere dream had become a fact. The School, now established on a firm basis, had in 1872 a faculty of 28 and a student body of 201, of whom 28 were graduate students. There had been 25 years of progress. While it had started as a simple school of applied chemistry, with special emphasis on the needs of agriculture, it had become during this quarter of a century an institution renowned in this country and recognized abroad.

Ex-President Woolsey, at the opening of North Sheffield Hall, referring to the fact that he was elected president of Yale College in 1846, said he "was present, so to speak, at the birth of this school. I have been thoroughly acquainted with the energetic efforts of the professors for its advancement. From the first they have struggled against probabilities. They have worked by faith.

They have aimed to have a school, sink or swim, worthy of the science of this country. During all these 26 years their constant aim has been to raise the standard of admission; to increase the excellence of the course of instruction, to raise the standard of the examinations for the degree, and in fact to raise the standard of the School in every particular. As a result, I think that there is, confessedly, no other school of this character in this country which is on a level with this." This is obviously home testimony, but, coming from the former president of Yale College, it carries weight.

If I have seemed in the course of this lecture to stress men as much or more than events, it is due to the fact that the character, strength and standing of any educational institution depend largely upon the men who compose the faculty. It is they who largely determine events, and the faculty of the Sheffield Scientific School from its inception in 1846 to 1872 was a group of remarkable men, broadly and thoroughly trained in their respective fields, recognized for their scientific accomplishments throughout the scientific world and exerting an influence here in New Haven and in Connecticut, not always recognized, but nevertheless one that brought credit and distinction to the State.

My story began with agriculture,—let me close with a few words on the same subject. Obviously the small State of Connecticut is not and never can be a great agricultural center, but what this country needed in the earlier years was not so much men to till the soil as men with knowledge and experience to bring science into active and visible cooperation with the toils and plans of the farm.

In 1856 Professor Johnson was made chemist to the Agricultural Society of the State, thus beginning his work on the applications of chemistry to agriculture. His first report made the following year was of such a nature as to arouse the farmers not only of Connecticut, but throughout the country, to a just appreciation of the many ways in which science could be made of service to them. This report of 1857 was the first agricultural publication of its kind in the United States. His work was attracting so much attention that in 1859 he was invited to deliver a course of lectures in Washington, at the Smithsonian Institution. The reports of these lectures attracted so much attention that he was led to make further endeavors to arouse general interest in the application of scientific

methods to improving agriculture. The result was two books, the one "How Crops Grow," published in 1868, the second, "How Crops Feed," published in 1870. No better evidence of the great value attached to this work and the widespread interest manifested can be furnished than by the fact that these books were translated into German, Italian, Swedish, Russian and Japanese, thus spreading throughout the world the new and revolutionary ideas which were destined to give a new approach to agriculture. As I have said before, Professor Johnson was the founder of the agricultural experiment stations of this country; the first was established in Connecticut and for a time was housed in the Sheffield Chemical Laboratory before moving to permanent quarters on Huntington Street.

At the time of Professor Johnson's death in 1909, President Hadley wrote, "It has been said that the most substantial contribution of the United States to applied science has been in using chemistry for the improvement of agriculture. Of this movement Professor Johnson was the leader. The whole system of agricultural experiment stations may well be regarded as his monument."

Among Professor Johnson's papers after his death was found the following memorandum with his signature, bearing on the influences which had surrounded the inception of the Agricultural Experiment Station of Connecticut.

"This station was the first permanent organization of the kind in America, and has largely grown out of the influence exerted by Professor John Pitkin Norton, a pupil of Johnston in Edinburgh and of Mulder in Utrecht, who in the year 1846 became professor of scientific agriculture in Yale College, and by his teachings and writings excited great interest in agricultural science and prepared the way for the application of scientific methods and results to improving our agriculture."

We thus have evidence of the growth and blossoming of the plant from the seed sown by John Pitkin Norton in 1847 in the School of Applied Chemistry. The 25 years of progress I have tried to depict is full of similar—though less striking—results, all the outcome of endeavors carried on during the first quarter-century of the Sheffield Scientific School.

INDEX

A

Agricultural chemistry, 86
 Agricultural experiment stations, 108
 American Turtle, Bushnell's, 27, 28
 Applied Chemistry, Yale School of,
 87, 88
 Armory, Whitney, 7-10
 Augur, Hezekiah, 11
 Austin, Henry, 12

B

Beecher, Edward, 23
 Blake, Eli Whitney, 9, 22, 34, 35
 Blotting paper, 23
 Brewer, William H., 102, 103
 Bridge, Mississippi River, 50, 51
 Bridge, Town's, 10, 12
 Brockett, John, 37-39
 Brush, George J., 95, 96
 Buell, Abel, 11
 Bushnell, David, 27, 28

C

Camp, Hiram, 22
 Canal, Erie, 46
 Canal, Farmington, 47
 Canal, Morris, 41, 42
 Canal, Northampton, 47
 Candee Rubber Company, 18
 Caoutchouc, 15
 Center Church, 12
 Central Park, New York, 52, 53
 Chicago and Rock Island R.R., 49-51
 Civil engineering at Yale, 93
 Clock manufacture, 19-22
 Clocks, exportation to England, 20
 Colt revolver, 8
 Cornell, Ezra, 33
 Cotton gin, description of, 4
 Cotton gin, invention of, 4-6
 Cotton gin, patent litigation, 5, 6
 Cotton production in U. S., 5

Coy, George W., 72-74
 Crockett, Davy, on New England in-
 ventors, 26

D

Dam, Lake Whitney, 7, 64
 Douglass, David Bates, 41-43
 Dwight, Timothy, on Bushnell's sub-
 marine, 28

E

East Rock Park, 51
 Eaton, Daniel C., 103
 Electric lighting, 76-81
 Electric telegraph, 32, 33
 Engineering, civil, at Yale, 93
 Engineering, Yale School of, 92
 English, James, 78-81
 Erie Canal, 46

F

Fair Haven and Westville Railway,
 66-68
 Farmington Canal, 47
 Farnam, Henry, 46-51
 Firearms, manufacture of, 6-8
 Franklin, Benjamin, 25
 Frost, Herrick P., 73

G

Gas lighting, 55-59
 Gilman, Daniel Coit, 100, 101
 Goodyear, Charles, 14-18
 Goodyear's book on gum elastic, 17, 18
 Gorry, Dr. John, 45
 Greene, Mrs. Nathaniel, 3, 4
 Gum elastic, 15, 18

H

Hadley, Arthur Twining, 46
 Hartford and New Haven R. R., 44
 Hayward, Nathaniel, 16, 17
 Henry, Joseph, 32, 33

Hillhouse, James, 47
 Hillhouse Mathematical Library, 104
 Hopkins Grammar School, 40
 Horsecars, 65-72
 Hurd, Davis, 47

I

Ice manufacture, 45, 46
 Interchangeable parts, 7, 8
 Inventors, New England, 26

J

Jerome, Chauncey, 8, 19-22
 Jerome Manufacturing Company, 21
 Johnson, Samuel W., 96

K

Kenyon College, 43

L

Laboratory teaching at Yale, 87, 88
 Land grant colleges, 101, 102
 Landscape architecture, 52, 53
 Lounsbury, Thomas Raynesford, 105
 Lyman, Chester S., 100

M

Mansfield, Jared, 39-41
 Mansfield, Stephen, 39
 Marsh, Othniel C., 104, 105
 Match-making machinery, 23
 Michigan Southern Railroad, 49
 Middlebury College, 44
 Miller, Phineas, 3, 4, 6
 Milling machine, 8, 9
 Mississippi River Bridge, 50, 51
 Mississippi River excursion, 59
 Mitchell, Donald G., 51
 Morris Canal, 41, 42
 Morse, Jedidiah, 29
 Morse, S. F. B., 28-32

N

New Haven Clock Company, 21, 22
 New Haven Electric Light Company,
 77, 78
 Northampton Canal, 47
 Northampton Railroad, 44, 48
 North, Simeon, 7, 8

Norton, John Pitkin, 85-92
 Norton, William Augustus, 93

O

Oil well, first, 54
 Olmsted, Frederick Law, 51-53

P

Park, Central, New York, 52, 53
 Park, East Rock, 51
 Parker, Joseph, 23
 Parmelee, Henry S., 23
 Peabody Museum, 105
 Porter, John Addison, 61, 64, 92, 101
 Putnam, Rufus, 40

R

Railroad, Chicago and Rock Island,
 49-51
 Railroad, Michigan Southern, 49
 Railroad, Northampton, 44, 48
 Railroads, New Haven, 44
 Railways, street, 65-72
 Refrigeration apparatus, 45, 46
 Rock Island Railroad, 49-51
 Root, Lauren F., 22
 Rubber or caoutchouc, 15

S

Sanford, Thomas, 23
 Sargent and Company, 23
 Science in early nineteenth century,
 83-85
 Scott, C. F., on Morse, 33
 Seamless Rubber Company, 18
 Sheffield Hall, 99, 104
 Sheffield, Joseph Earl, 48-50, 98-100
 Sheffield Scientific School, founding
 of, 83-108
 Sheffield Scientific School, name, 99
 Silliman, Benjamin, 30, 43, 45, 52
 Silliman, Benjamin, Jr., 53, 54, 87, 90
 Snelling, Job and family, 26
 Southern New England Telephone
 Co., 76
 Sprinklers, automatic, 23
 Stone-breaker, Blake's, 35
 Street, Augustus R., 14

Street lighting, early opposition to, 58

Street railways, 65-72

Submarine, Bushnell's, 27, 28

Surveying, public lands in middle west, 40

Surveying, seventeenth century, New Haven, 38

T

Telegraph, electric, 32, 33

Telephones, 72-76

Terry, Eli, 8, 19

Town, Ithiel, 12-14

Town, Ithiel, residence and gallery, 14

Town's bridge, 10, 12

Truss, lattice, 13

Truss, Town, 13

Twining, Alexander Catlin, 43-46, 48, 61, 62

U

United Illuminating Company, 80

United States Military Academy, 40, 44

V

Vail, Alfred, 32

Verrill, Addison E., 103

Vulcanization, Goodyear's invention of, 17

W

Walker, Francis Amasa, 105

Water supply, 45, 47, 59-65

Water supply, municipal ownership debate, 60-63

Water supply, New York City, 42

West Point, U. S. Military Academy, 40, 44

Whitney armory, 7-10

Whitney, Eli, 3-10

Whitney, Eli II, 9, 62-65

Whitney, Eli III, 10

Whitneyville armory, 7-10

Whitney, William Dwight, 100

Winchester Repeating Arms Company, 23

Y

Yale College in early nineteenth century, 29, 30, 35, 87

Yale School of Applied Chemistry, 87, 88

Yale School of Engineering, 92

Yale School of Fine Arts, 14

Yale Scientific School, 95

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